Musculoskeletal

Tumors & Infection

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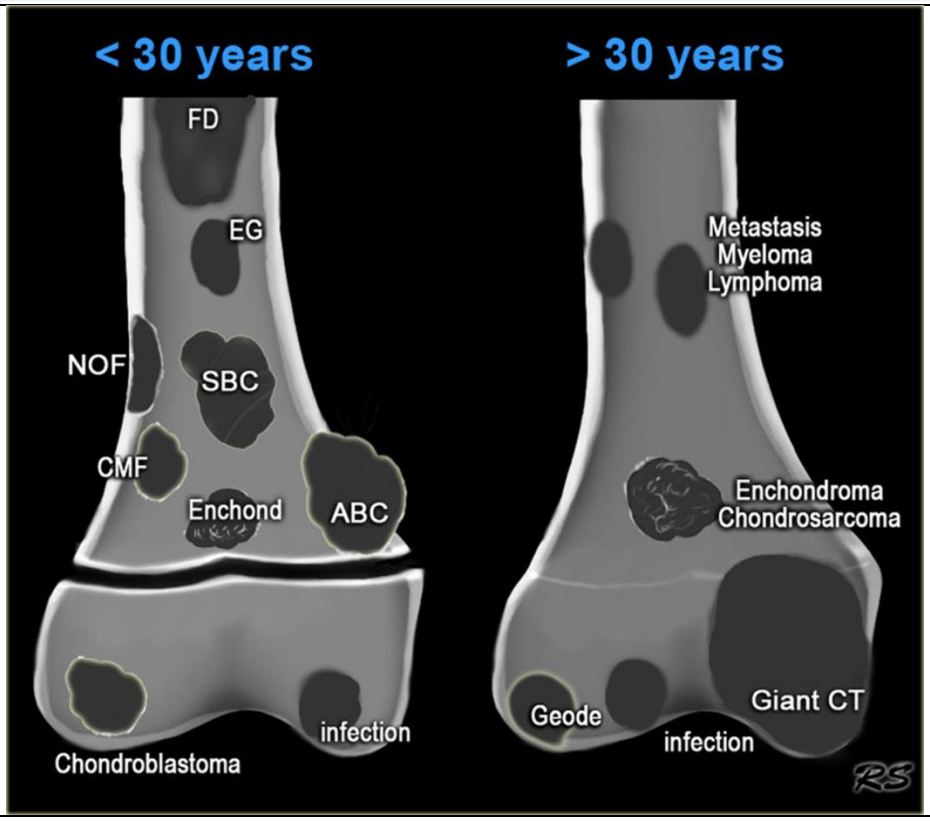
Bone Tumors

☺ Bone Tumors Approach ☺

A- Patient Age:

Peak Age Predilection of Bone Lesions

Age (y)	Benign	Malignant
<20	Fibrous cortical defect, nonossifying fibroma, simple bone cyst, aneurysmal bone cyst, chondroblastoma, Langerhans cell histiocytosis, osteoblastoma, osteoid osteoma, osteofibrous dysplasia, chondromyxoid fibroma, fibrous dysplasia, enchondroma	Leukemia, Ewing sarcoma, osteosarcoma (conventional, periosteal, telangiectatic), metastatic disease (rare), neuroblastoma, retinoblastoma, rhabdomyosarcoma, Hodgkin lymphoma
20–40	Enchondroma, giant cell tumor, osteoblastoma, osteoid osteoma, chondromyxoid fibroma, fibrous dysplasia	Osteosarcoma (parosteal), adamantinoma
>40	Fibrous dysplasia, Paget disease, non-Hodgkin lymphoma, chondrosarcoma, malignant fibrous histiocytoma, osteosarcoma (secondary to Paget disease and radiation)	Metastatic disease (most common), myeloma



B- Bone Lesion Location

Typical Locations of Bone Lesions

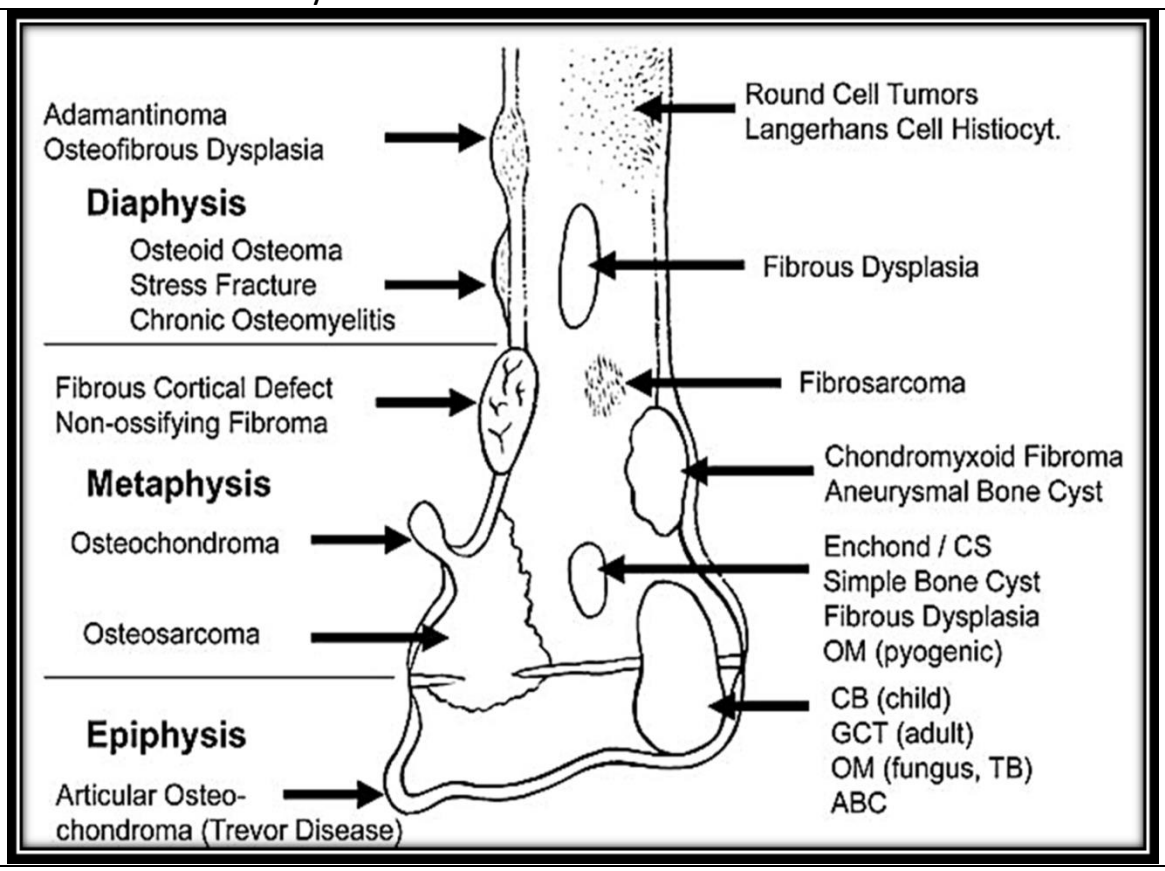
Location	Benign	Malignant
Epiphyseal (end of bone)	Chondroblastoma (skeletally immature patient)	Clear cell chondrosarcoma (exceedingly rare tumor)
	Giant cell tumor (skeletally mature patient)	
	Osteomyelitis (pyogenic: starts in metaphysis and may spread to epiphysis if the person is <18 mo old; tuberculosis or fungus at end of bone in skeletally mature person)	
	Paget disease	
	Intraosseous ganglion/geode (should have associated arthritis)	
	Osteochondral injury	
Metaphyseal		
Medullary	Simple (unicameral) bone cyst (centrally located)	Conventional osteosarcoma
	Aneurysmal (multicameral) bone cyst (eccentrically located; may be engrafted on other lesions such as giant cell tumor and chondroblastoma)	Chondrosarcoma
	Enchondroma (centrally located)	Metastatic disease
	Fibrous dysplasia	Myeloma (over age 40)
	Osteomyelitis (typical location for pyogenic infection in children >18 mo and adults)	Lymphoma
	Localized Langerhans cell histiocytosis	Malignant vascular tumors (very rare; angiosarcoma, hemangiopericytoma)
	Chondromyxoid fibroma (eccentrically located)	
Cortical	Fibrous cortical defect and nonossifying fibroma (lytic in children, fills in and involutes in adults)	Metastatic disease (especially lung)
	Osteoid osteoma (small lucent nidus with surrounding fusiform reactive sclerosis)	
Juxtacortical	Juxtacortical chondroma (arises from periosteum)	Periosteal osteosarcoma (arises from deep cambian layer of periosteum)
		Parosteal osteosarcoma (arises from a superficial layer of periosteum)
		Juxtacortical chondrosarcoma (arises from the periosteum)
Diaphyseal (shaft)		
Medullary	Fibrous dysplasia	Ewing sarcoma (may also occur in the metaphysis and in flat bones: eg, calvarium, pelvis, mandible, ribs; reflecting red marrow distribution)
	Localized Langerhans cell histiocytosis (may also occur in metaphysis and flat bones, eg, calvarium, pelvis, mandible, ribs)	Lymphoma
		Myeloma (occurs in red marrow sites, eg, axial skeleton and proximal aspects of humeri and femora)
		Metastatic disease (may be medullary or cortical)
		Malignant vascular tumors (very rare; angiosarcoma, hemangiopericytoma)
Cortical	Ossifying fibroma (ie, osteofibrous dysplasia or Campanacci lesion)	Adamantinoma (mixed lytic and sclerotic lesion occurring almost exclusively in anterior cortex of tibia; tibia may be bowed; look for satellite lesion in tibia or adjacent fibular involvement)
		Metastatic disease (especially lung)

Longitudinal Location

- Epiphyseal
- Metaphyseal
- Diaphyseal

Transverse Location:

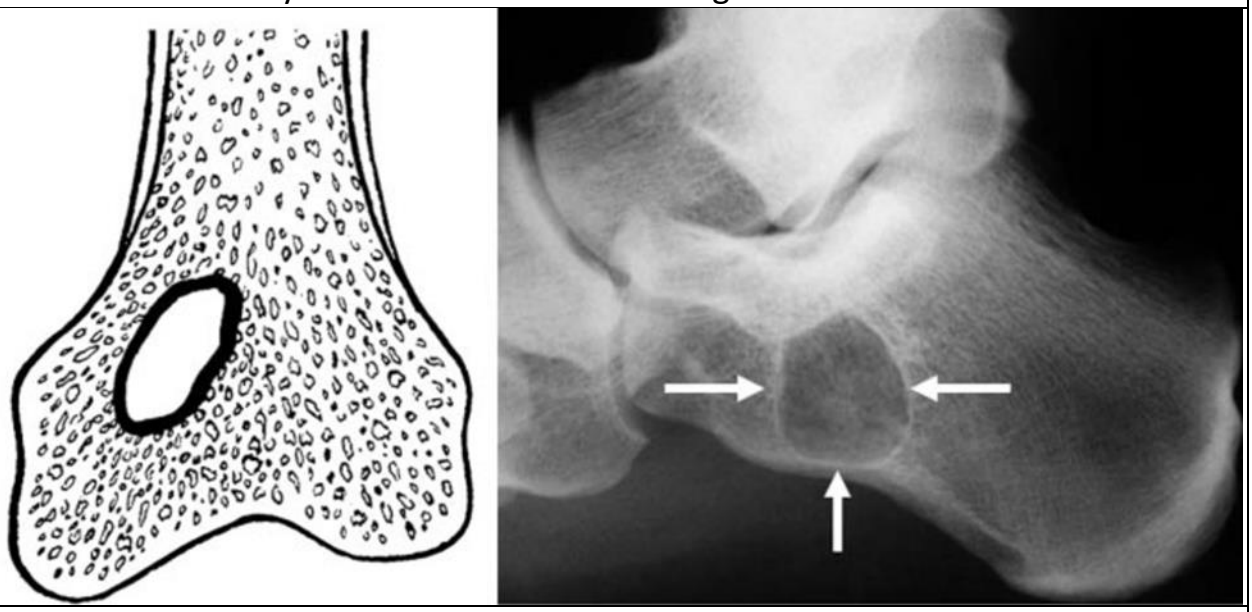
- Juxtacortical
- Cortical
- Eccenteric
- Central medullary



C- Bone Lesion Margin

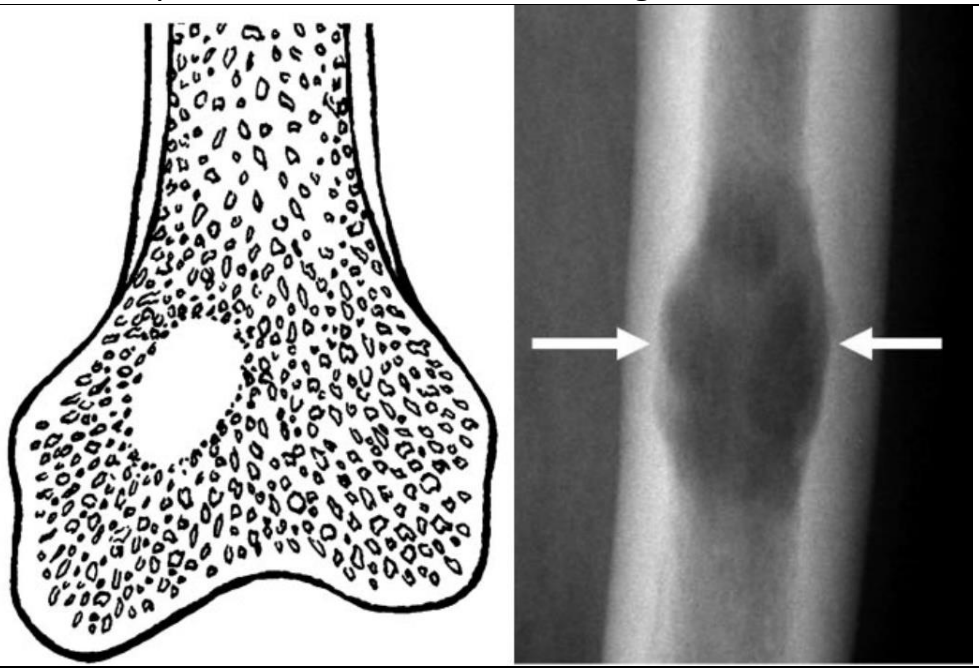
Type 1a Geographical lesion =

Well defined osteolytic lesion with sclerotic margin



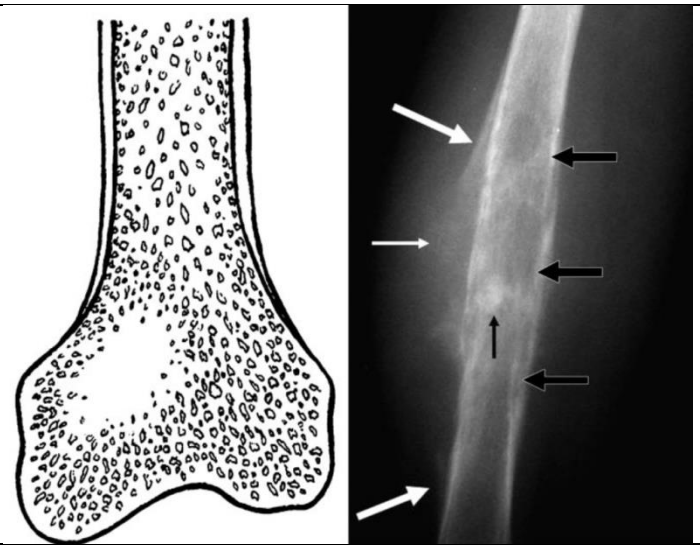
Type 1b Geographical lesion =

Well defined osteolytic lesion with no sclerotic margin



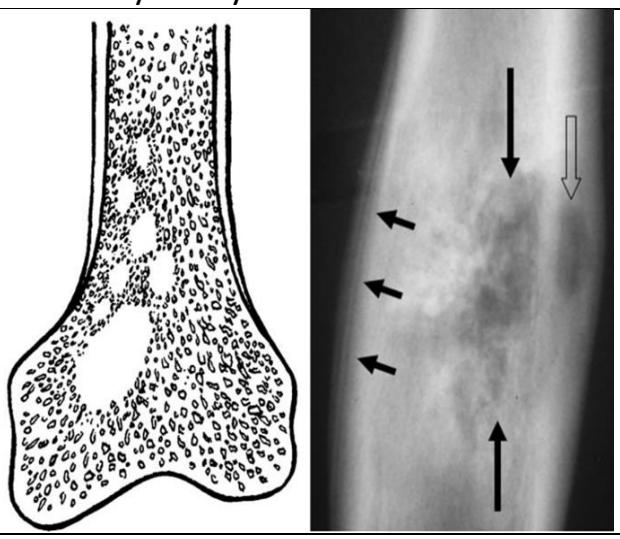
Type 1c Geographical lesion =

= Ill defined lytic lesion with narrow zone of transition



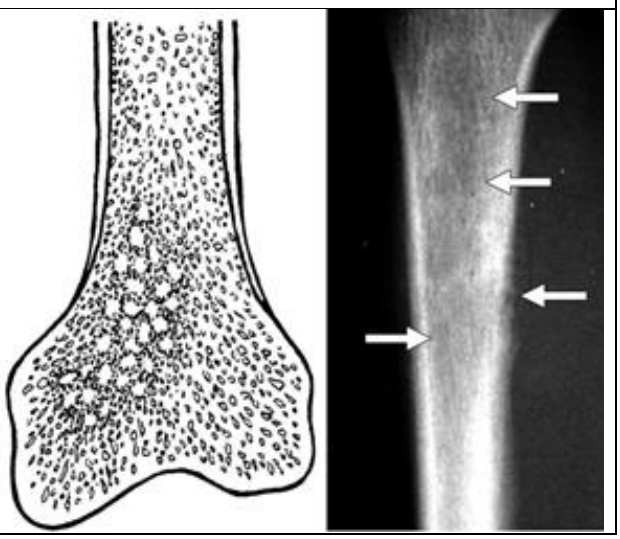
Type 2= Moth-eaten appearance =

Ill defined patchy lytic lesion of medullary cavity



Type 3 Permeative appearance =

ill defined lytic lesion with wide zone of transition.



D- Bone Lesion Matrix

Chondroid matrix in cartilaginous tumors:

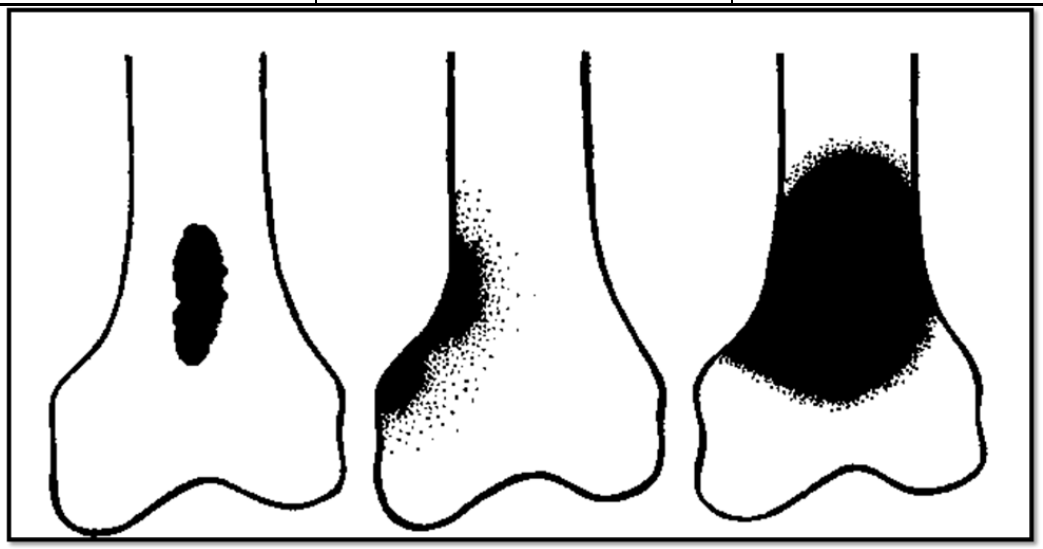
- Enchondroma
- Chondrosarcomsa

Osteoid matrix in osseus tumors:

- Osteoid osteoma
- Osteosarcoma

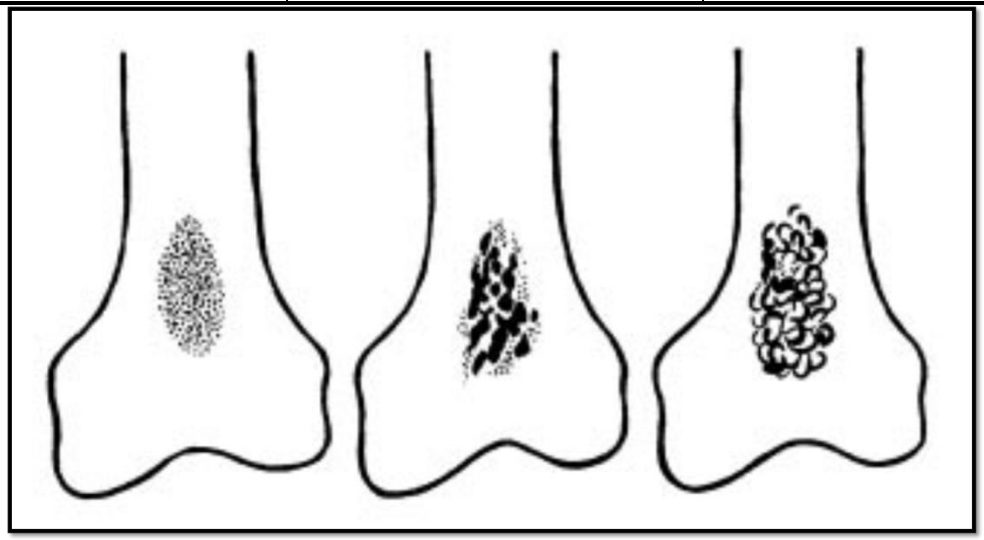
1) Osseous Matrix

Solid	Cloud	Ivory



2) Chondroid Matrix

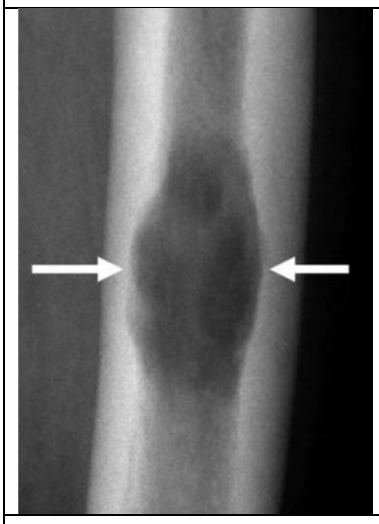
Stippled	Flocculent	Ring & Arc



E-Cortical Response

- Endosteal Scalloping
  - Benign lesions
- Ballooning
  - GCT = Giant cell tumor
  - CMF = Chondromyxoid fibroma
- Complete cortical destruction
  - Aggressive malignant
  - Osteomyelitis
- Permeative growth
  - Ewing sarcoma
  - Lymphoma

1) Endosteal Scalloping



2) Ballooning

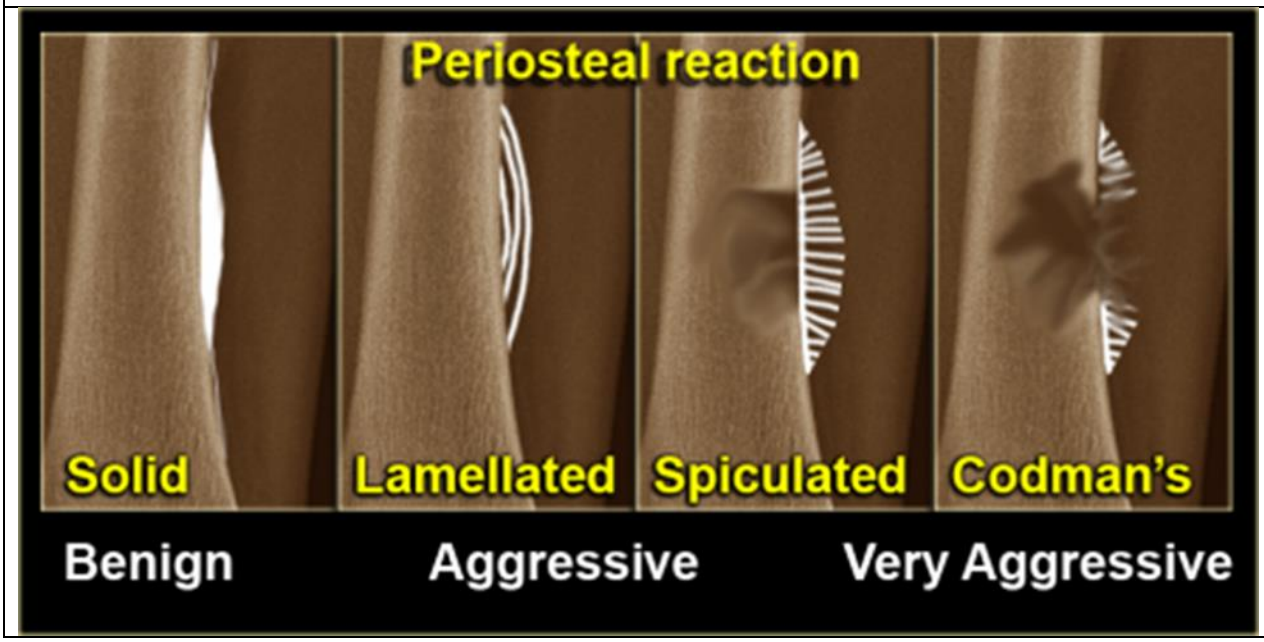
CMF

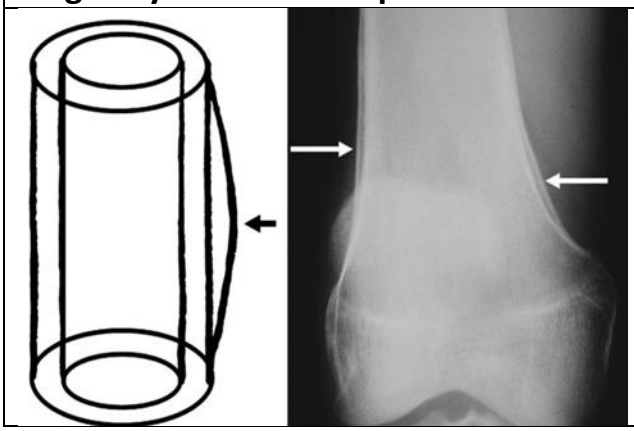
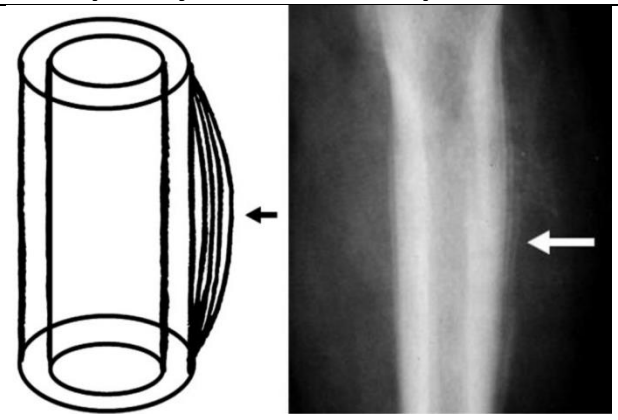
GCT

3) Cortical Destruction

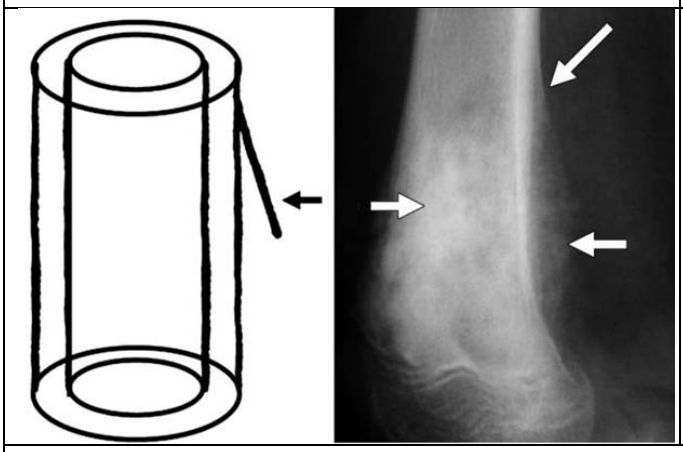
4) Cortical Permeation => ES

F-Periosteal Reaction

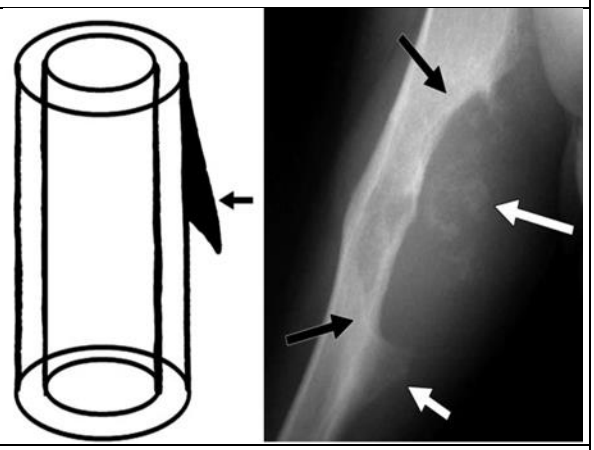


1) Unilamellated = Single layer of reactive periosteum	2) Multilamellated = Onion skin Multiple layers of reactive periosteum
	

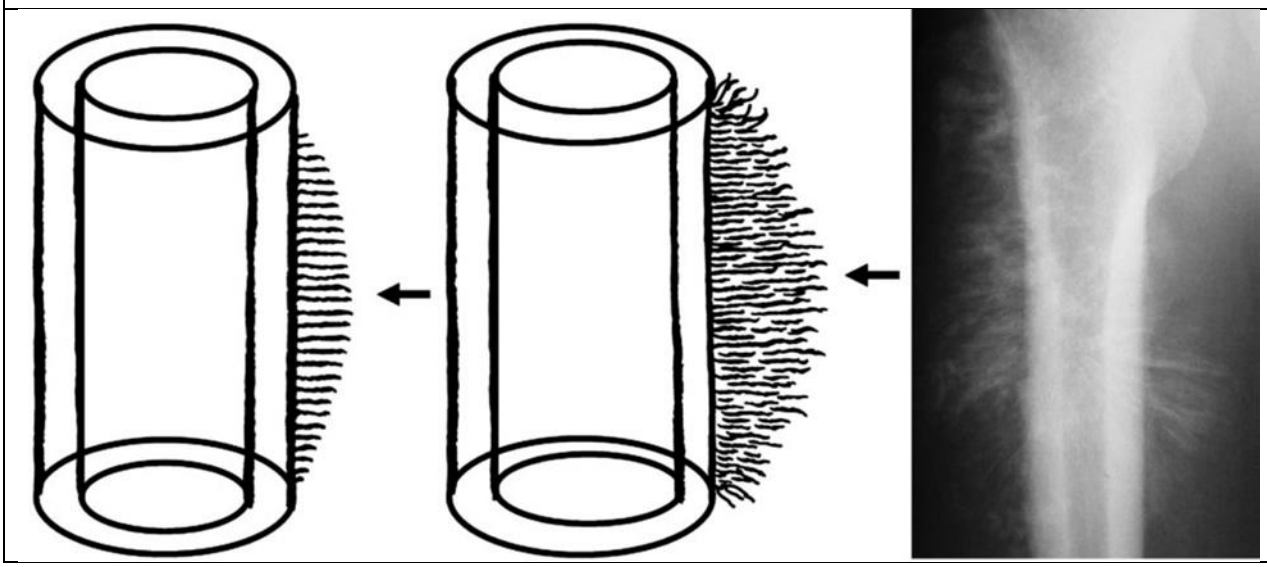
3) Codman Triangle =
Elevated periosteum forming angle with cortex



4) Buttress periosteal reaction =
elevated periosteum form beak like
=> Juxtacortical chordoma / Condrosarcoma



5) Sunburst Appearance =
Radial periosteal reaction peripendicular to cortex => Osteosaroma



I- Epiphyseal Lesions

- **Chondroblastoma (Child)**
- **Giant Cell Tumor (Adult)**
- **Brodie's Abscess**
- **Intraosseous ganglion cyst.**
- **Geode cyst**
- **Clear cell chondrosarcoma**

1) Chondroblastoma

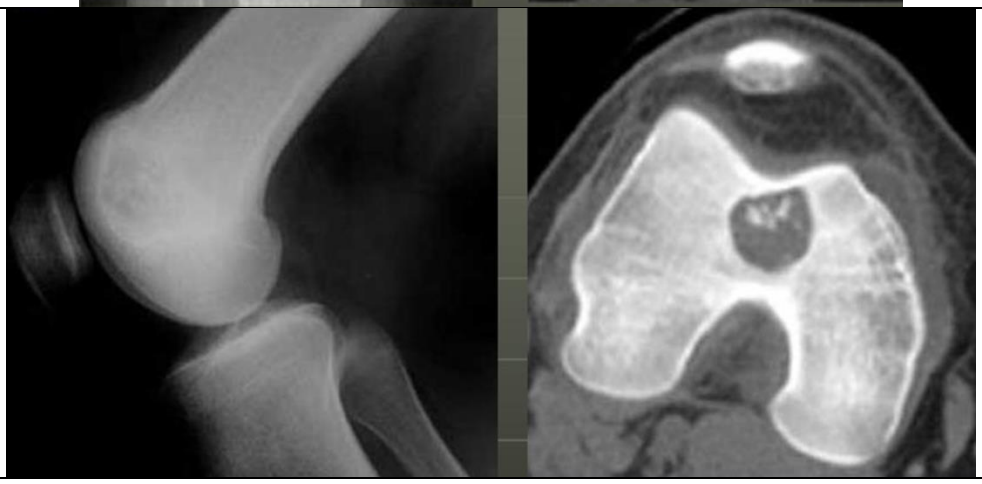
- Benign tumor of bone characterized by chondroblasts and multinucleated giant cells.
- Age: 5 – 25 y

Location & Distribution:

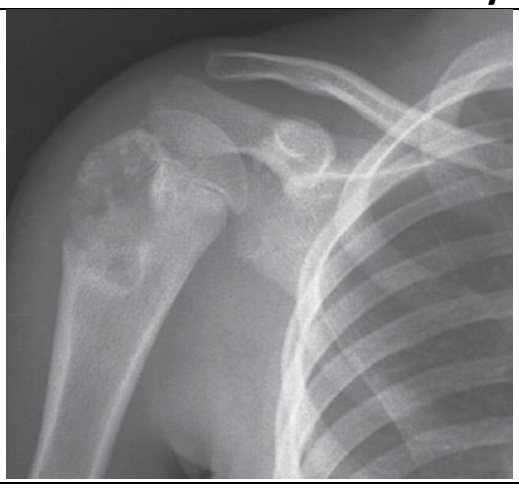
- Around knee (50%): Femur (33%), and tibia (20%).
- Humerus (20%)
- Epiphysis or apophysis of a bone.
- +/- metaphyseal extension
- Centrally or eccentrically located

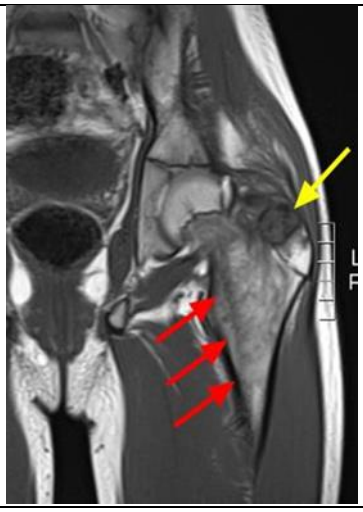
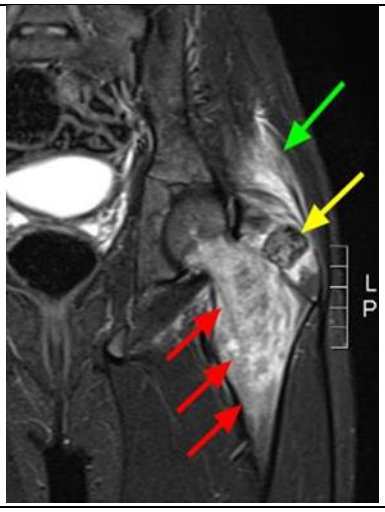
Radiological findings:

- A well-defined Osteolytic lesion
- Surrounded by sclerotic rim
- Matric Calcification
- T2: Cobblestone pattern (high singal)



Patella	Calcaneus

Head of fibulla	Greater Humeral Tuberosity
	

Greater Femoral Trochanter		
		

2) Giant Cell Tumor

- Age: 3rd – 4th decade of life

Location & Distribution:

90%: Metaphyseal subarticular in long bones:

- Distal Femur
- Proximal Tibia
- Distal Radius

10%: Flat bones: sacrum

Radiographic Appearance

- A well-defined expansile osteolytic lesion
- In adults, it frequently extends to the articular surface of the bone,
- In children the physis may impede the growth of the lesion into the epiphysis.
- **NO sclerotic margins.**
- **NO matrix calcifications.**
- Cortical thinning and mild expansion may be evident and can break through the cortex.

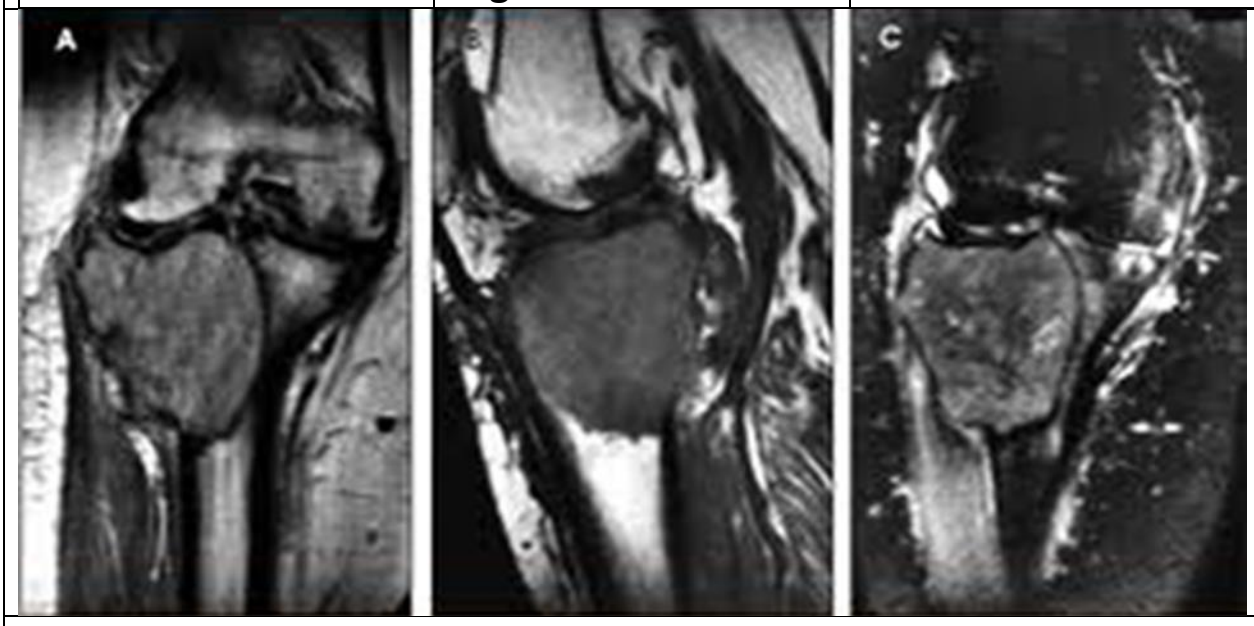
MRI:

MRI depict sharp demarcation with low signal intensity owing to the deposition of hemosiderin at the periphery of the tumor.

T1: Homogenous low SI

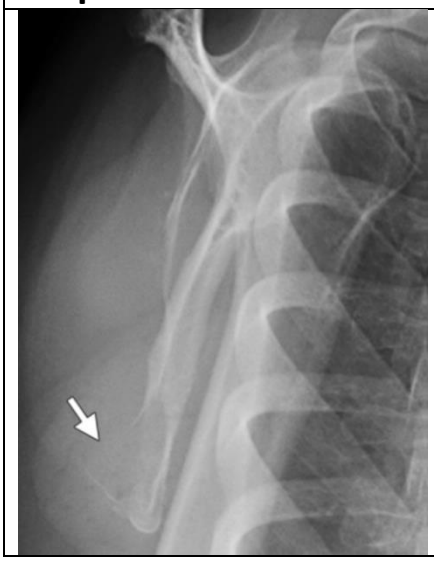
T2: Heterogeneous low SI in a whorled or uniform pattern from hemosiderin and collagen deposition and high cellularity.

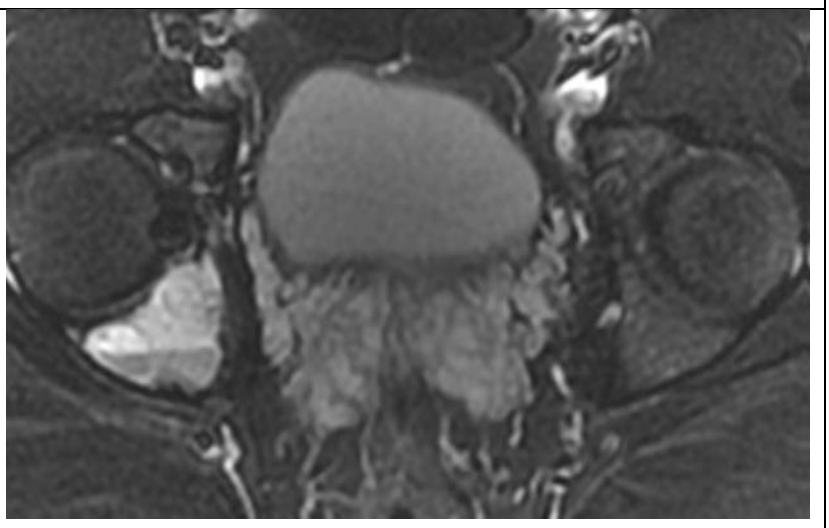
Coronal T1	Sagittal T1	Coronal T2



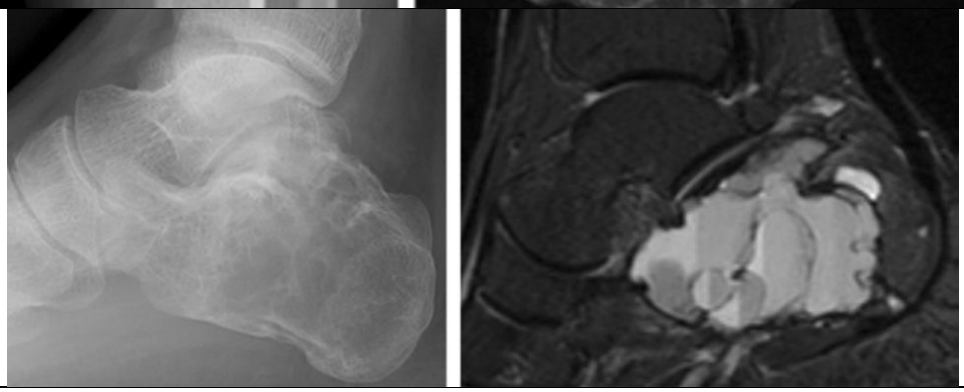
❖GCT In Flat Bones

Scapula	Pelvis



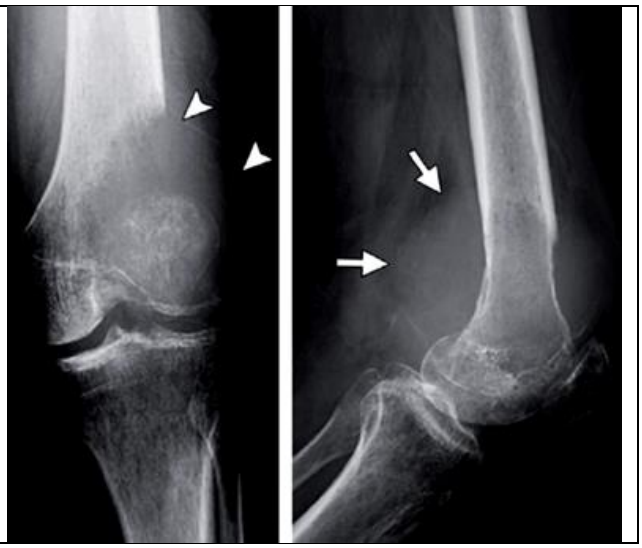


❖GCT with 2ry ABC formation



❖ Aggressive GCT

- Wide zone of transition,
- Cortical thinning,
- Expansile remodeling,
- Cortical bone destruction
- Associated soft-tissue mass



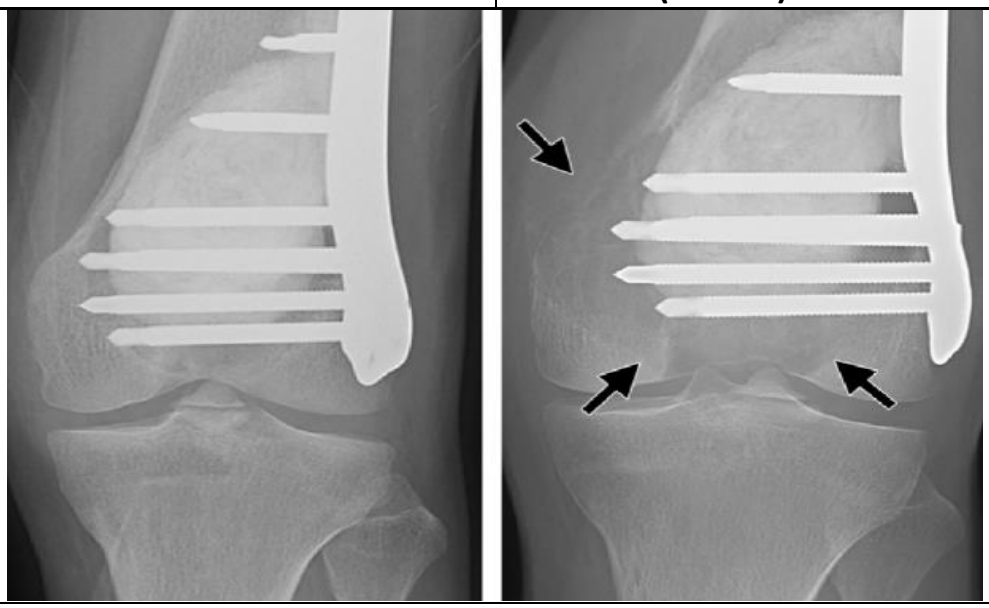
❖Malignant transformation of GCT

High-grade Sarcoma	Pulmonary Metastasis

❖ Pathologic Fracture Associated With GCT:	❖ GCT treated with curettage and allograft placement

❖ Recurrence of GCT

GCT after treatment with curettage and cement placement	**Follow-up 8 months later shows increased lucency at the bone-cement interface (arrows).**

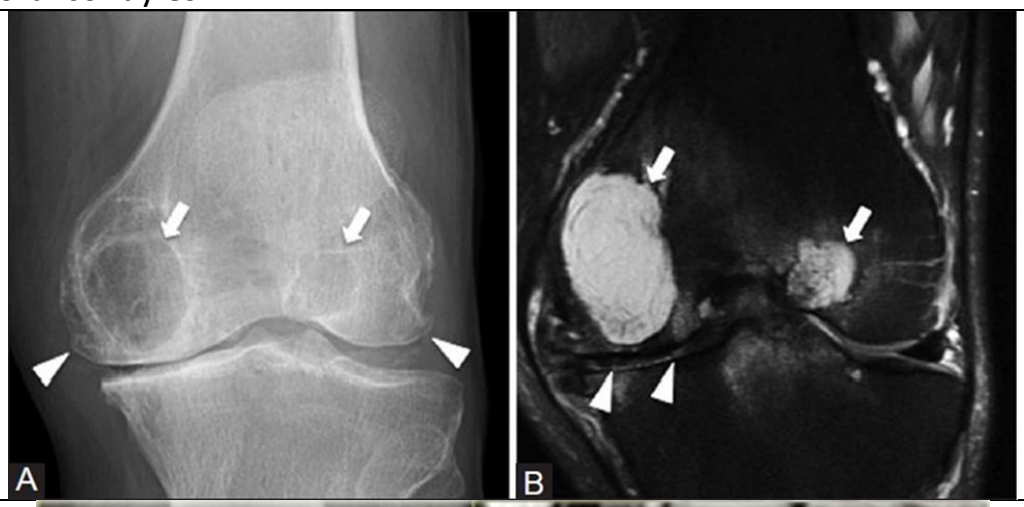


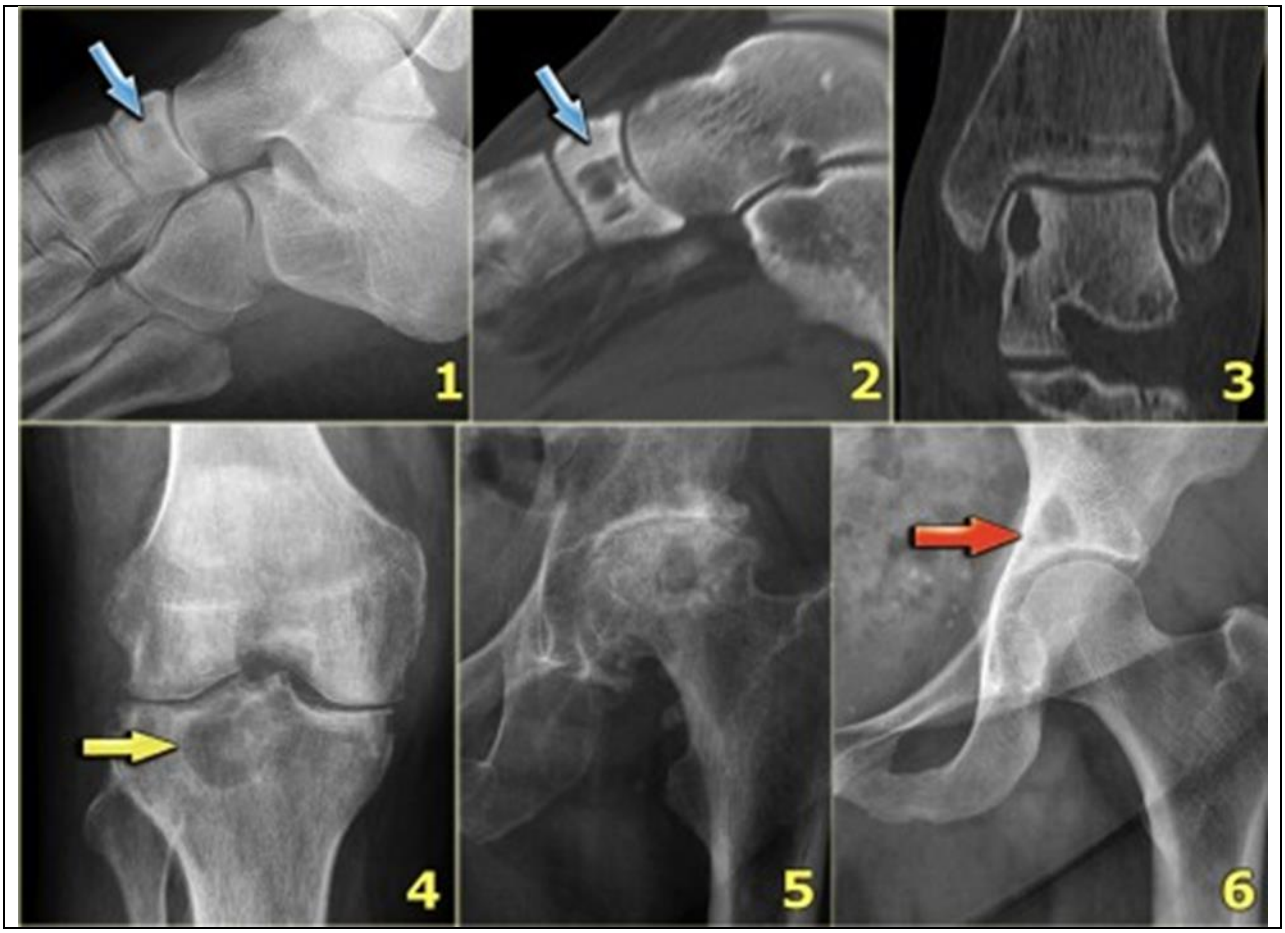
❖ Postoperative Infection

GCT in the calcaneus after treatment with curettage and cement placement	18 months later shows increased lucency due to osteomyelitis and interval placement of antibiotic- impregnated cement beads (arrows) within the calcaneus

3) Geode

- = Subchondral Degenerative cyst.
- Degenerative osteoarthritis
- Narrowing of joint space
- Marginal osteophytes
- Large subarticular lucencies with sclerotic rims in the medial and lateral femoral condyles.

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4) Intraosseous Ganglion Cyst

- Intraosseous ganglion cysts are benign lesions that may cause occasional discomfort.
- Conservative management with NSAIDS is the first line of treatment, but curettage or excision is typically curative.

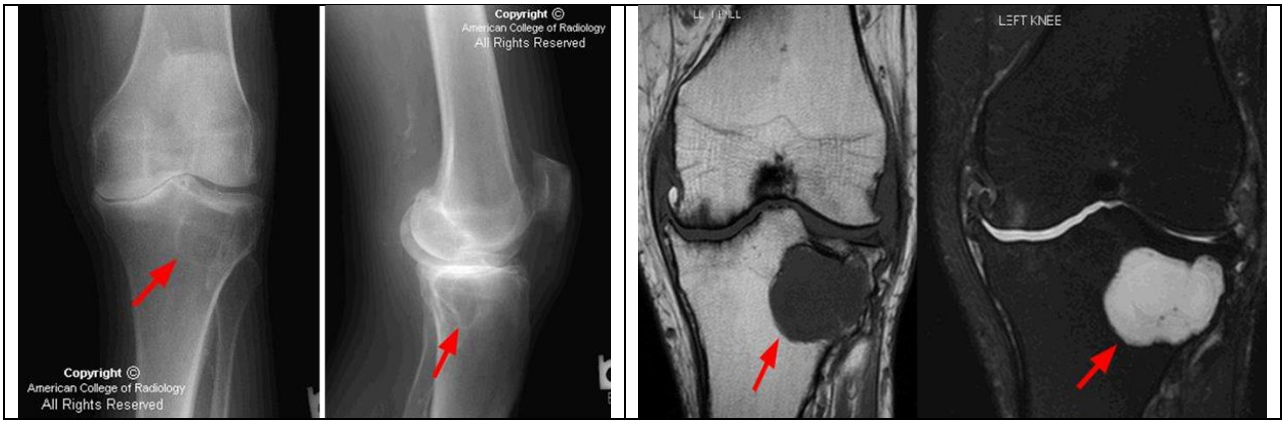
- They occur in the subchondral regions of tubular bones, the

Common sites include

- Femoral heads, distal portions of the radius and ulna, distal end of the femur, proximal aspect of the tibia, and medial malleolus. acetabulum, and in the carpal bones.

Radiological findings:

- Well defined osteolytic lesion with central or eccentric location
- Well-defined sclerotic borders,
- Typically occur near a joint surface in subchondral bone.
- T1: low signal intensity
- T2: bright signal intensity



5) Brodie Abscess

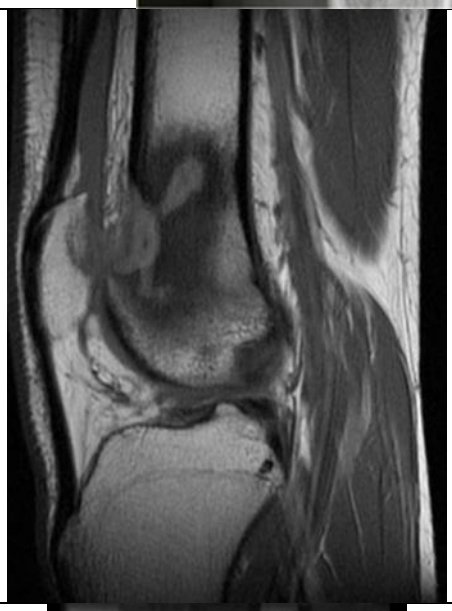
A Brodie abscess refers to an abscess related to focus of chronic osteomyelitis in a bone.

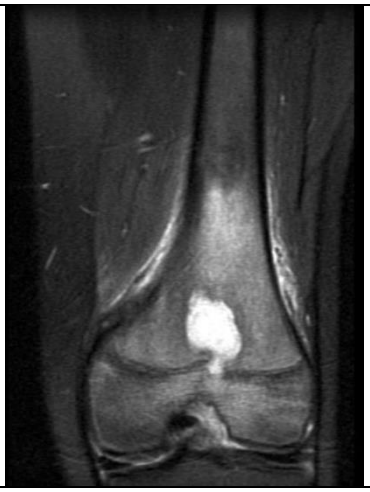
Radiographic Findings:

- Lytic lesion often in an oval configuration that is oriented along the long axis of the bone
- Surrounded by thick dense rim of reactive sclerosis that fades imperceptibly into surrounding bone
- Lucent tortuous channel extending toward growth plate prior to physeal closure (pathognomonic)
- Periosteal new-bone formation
- ± adjacent soft-tissue swelling
- May persist for many months

MRI:

- Oval shaped lesion of low T1 and high T2 signal.
- Surrounded by hypointesne signal rim.
- Surrounded by bone marrow edema.





II- Juxtacortical Lesions

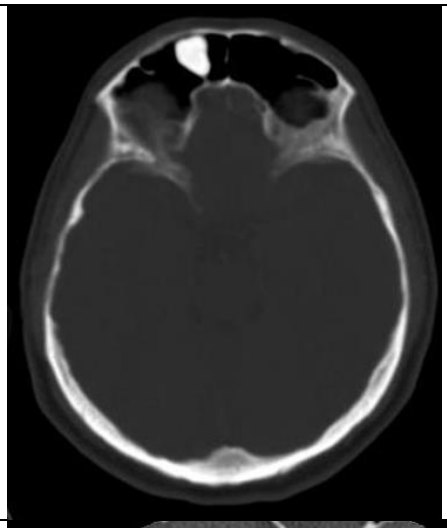
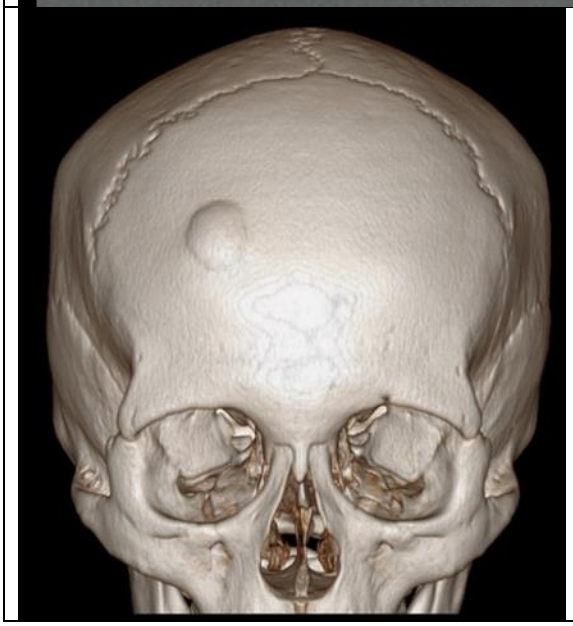
- **Osteoma**
- **Osteochondroma**
- **Juxtacortical ABC**
- **Juxtacortical chordoma**
- **Juxtacortical chondrosarcoma**
- **Surface Osteosarcoma (See Osteosarcoma)**
  - **Paraosteal OS**
  - **Periosteal OS**
  - **High grade surface OS**

1) Osteoma

- Osteoma is a slow-growing lesion that may arise from the cortex of the skull or the frontal/ethmoid sinuses.
- Gardner syndrome is an autosomal dominant syndrome of multiple osteomas, intestinal polyposis, and soft-tissue desmoid tumors.
- DD: osteochondroma: No medullary continuation.

Location & Distribution:

- **Paranasal sinus osteoma**
- **Skull vault osteoma**
- **Mandibular osteoma**

2) Osteochondroma

- is the most common benign bone neoplasm
- 35% of all benign bone tumors
- 9% of all bone tumors
- Growth will continue during skeletal growth and stops when the epiphysiseal growth plates have fused

Location and Distribution:

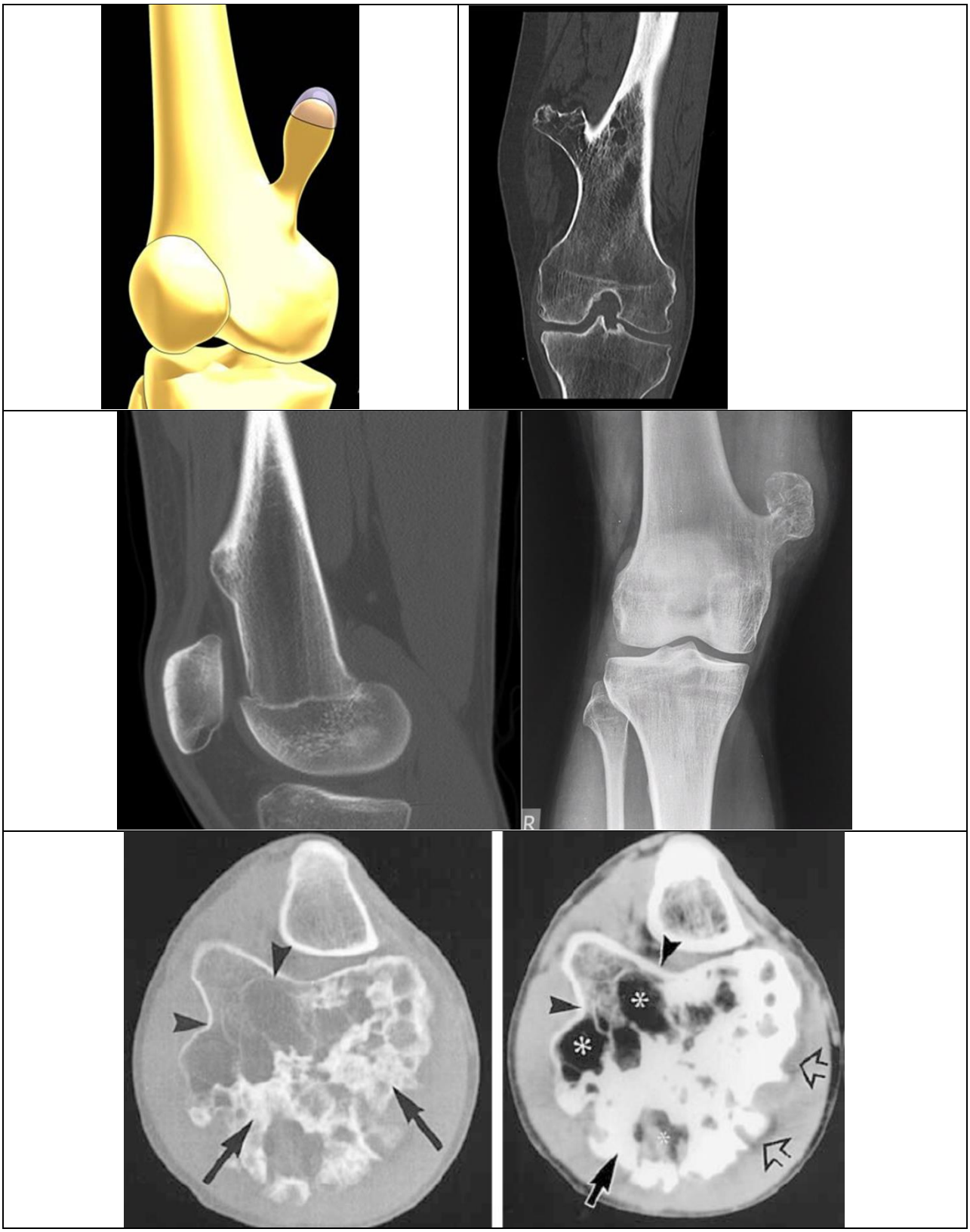
- **Lower limb: 50% of all cases**
    - Femur (especially distal): most common: 30%
    - Tibia (especially proximal): 15-20%
    - Less common locations: feet
- **Upper limb:**
    - Humerus: 10-20%
    - Less common locations: hands
- **Spine:** the posterior elements of spine are an uncommon, but not rare.

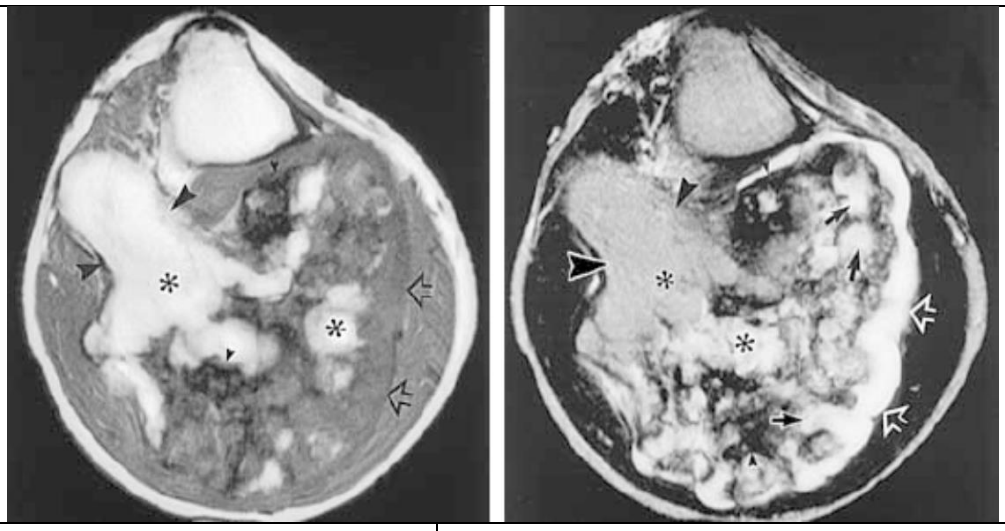
Imaging Features:

- Metaphyseal outgrowth
- Narrow based (pedunculated) or broad based (sessile)
- Project away from joint
- Cortical and medullary continuation with the mother bone
- Cartilaginous cap of high T2 signal < 1cm

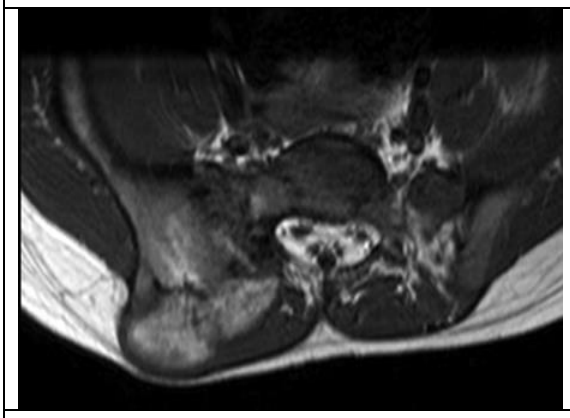
Complications:

- Pain
- Pressure
    - Joint functional restriction
    - Bursitis
    - Tendinosis
    - Vascular compromise
    - Neurological sequelae
- Fracture
- Cosmetic discomfort

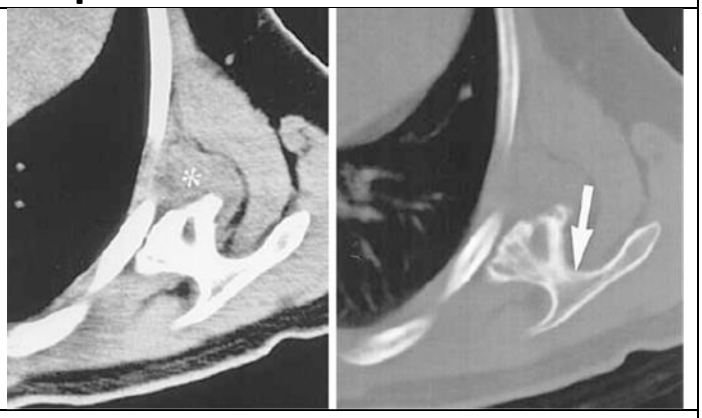




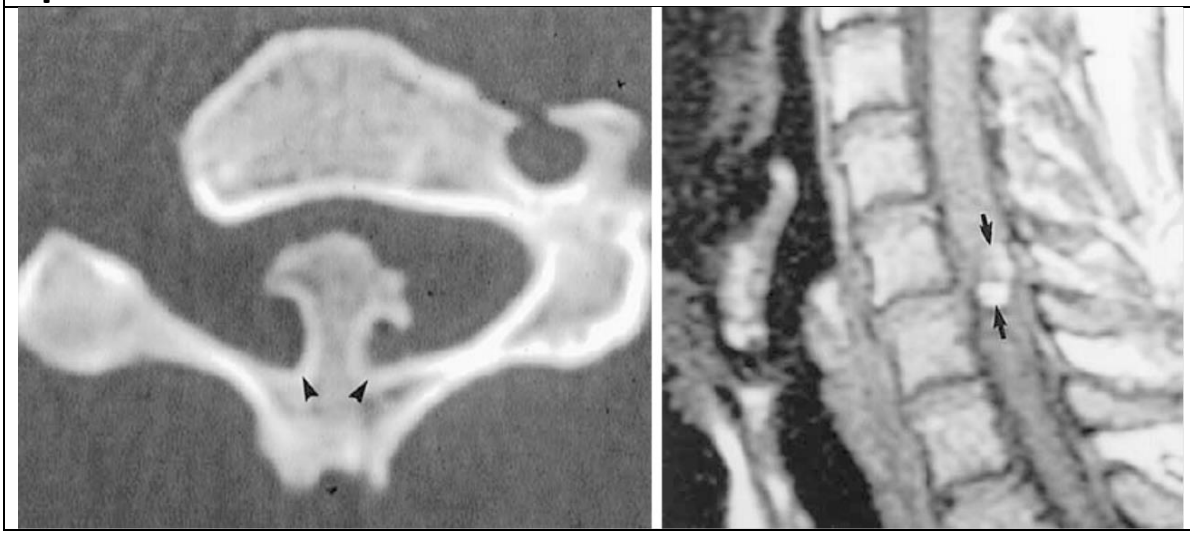
Pelvis



Scapula

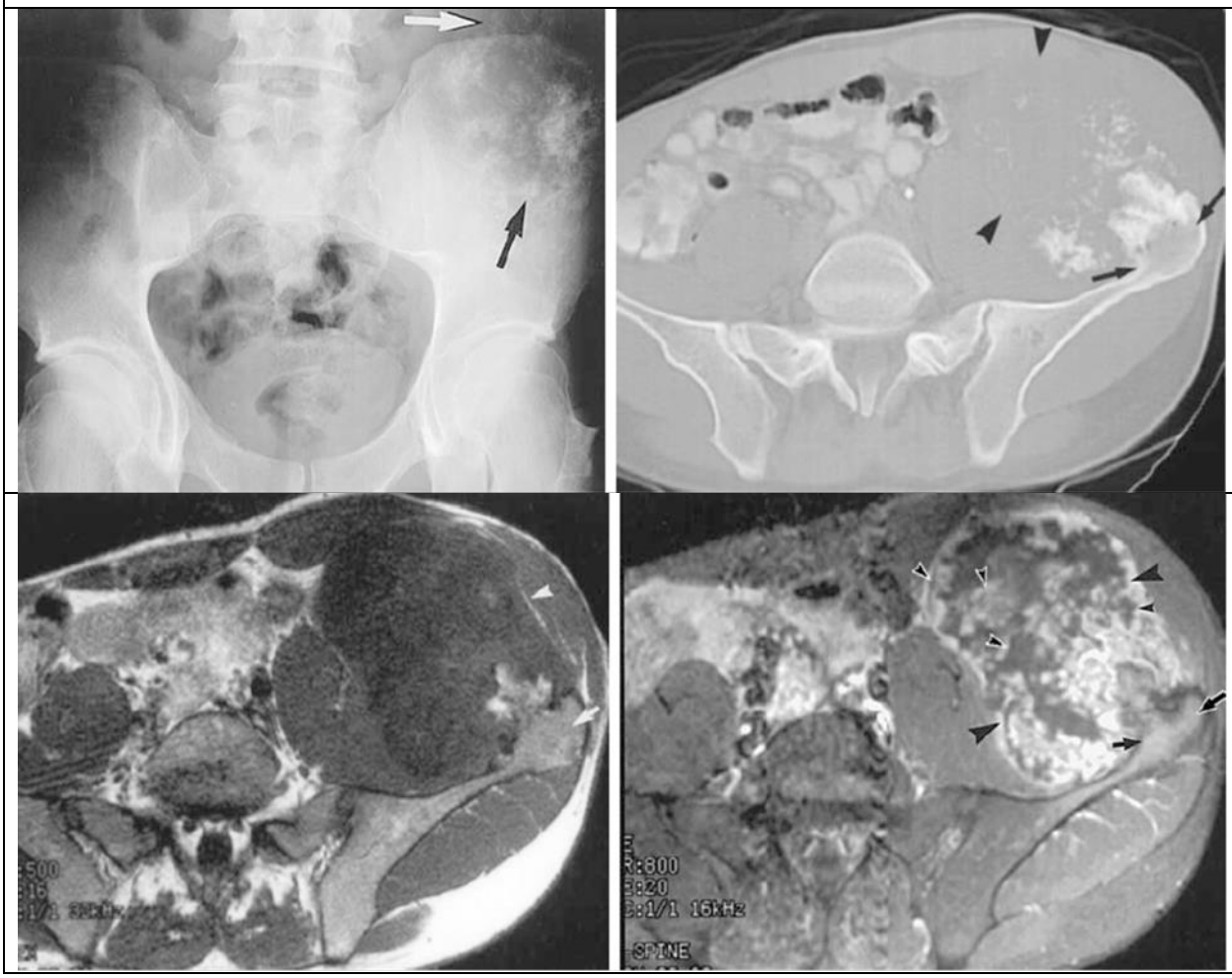


Spine



❖ Malignant Transformation => 2ry Chondrosarcoma

- New onset of growth after skeletal maturity
- Medullary invasion
- Cortical destruction
- Soft tissue invastion
- Cartilagenous cap
    - 1.5 cm in Adults
    - > 3 cm in children



❖ Hereditary Multiple Exostoses (HME) = Diaphysial Achalasia

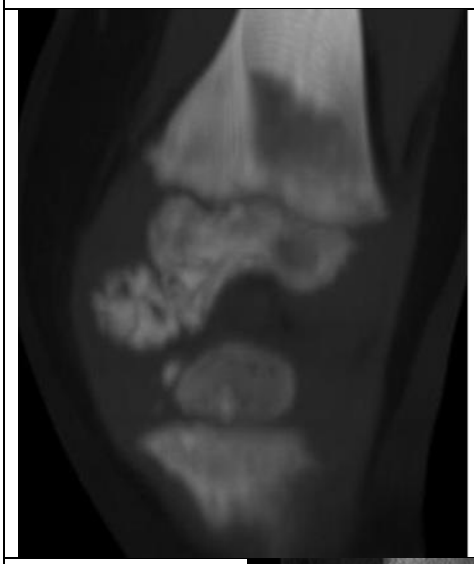
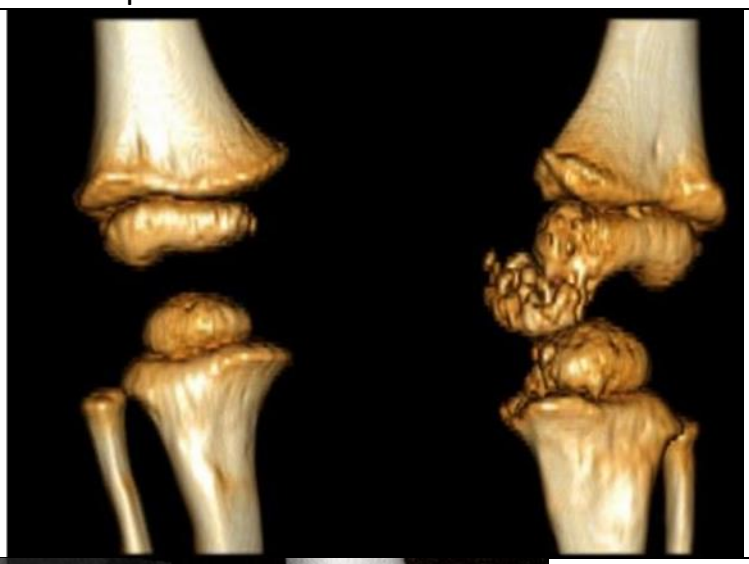
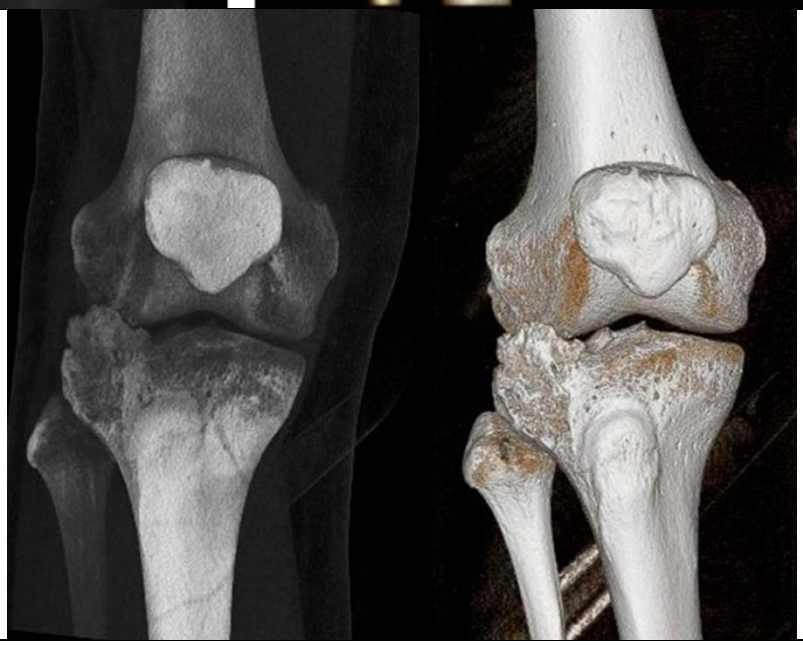
- Autosomal dominant condition
- Short stature
- Multiple osteochondromas
- Asymmetric growth at the knees and ankles
- Risk of malignant degeneration is 1-20%

❖ Dysplasia Epiphysealis Hemimelica = Trevor Disease

- Extremely rare non hereditary disease
- Osteochondroma arising from the epiphyses.

<u>3 types:</u>

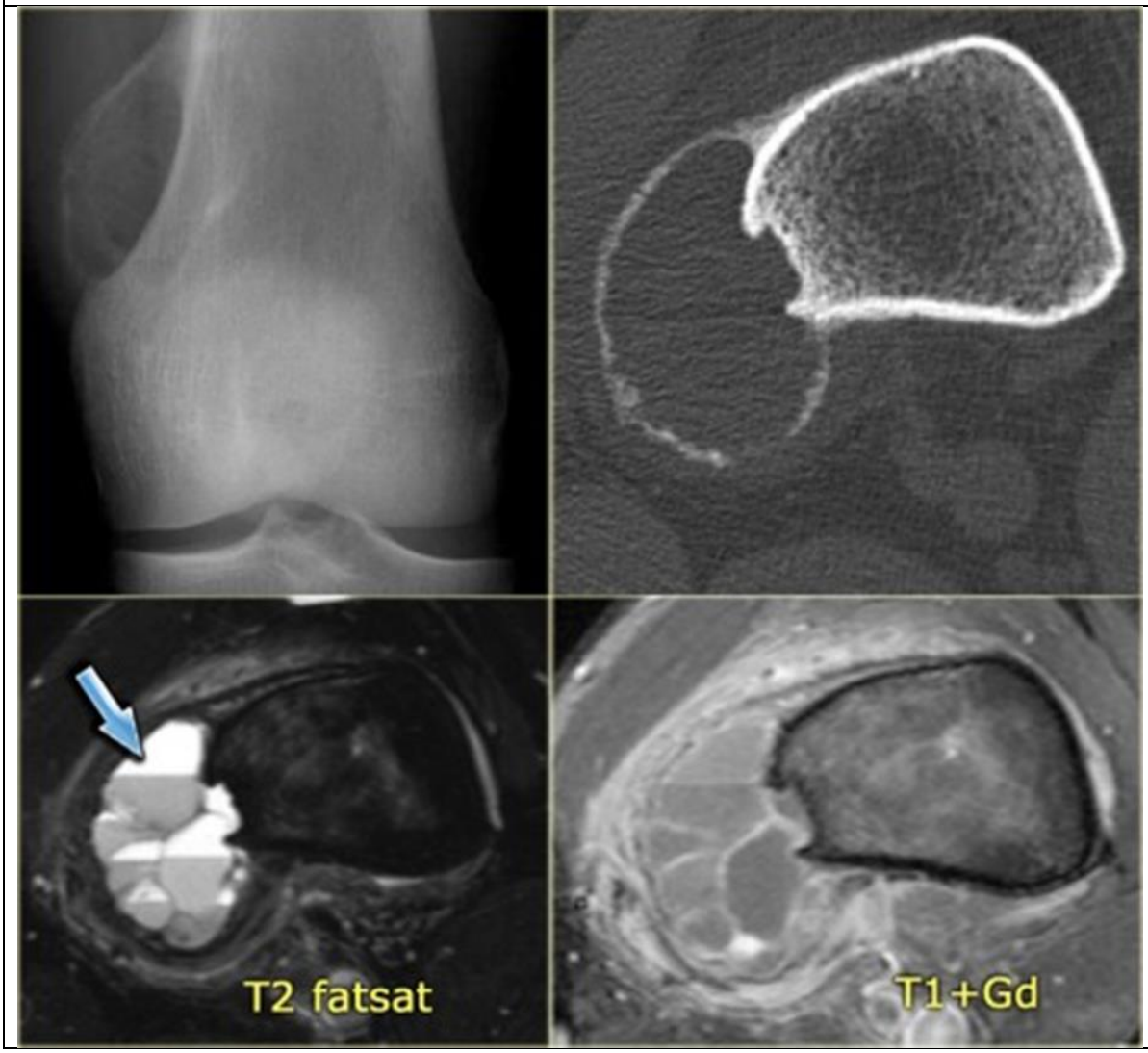
- Classic form: > one bone or epiphysis within a single lower extremity.
- Localized form: single bone affection.
- Generalized form: Whole limb from pelvis to foot.

❖ Bizarre Parosteal Osteochondromatous Proliferation (BPOP) = Nora Lesion

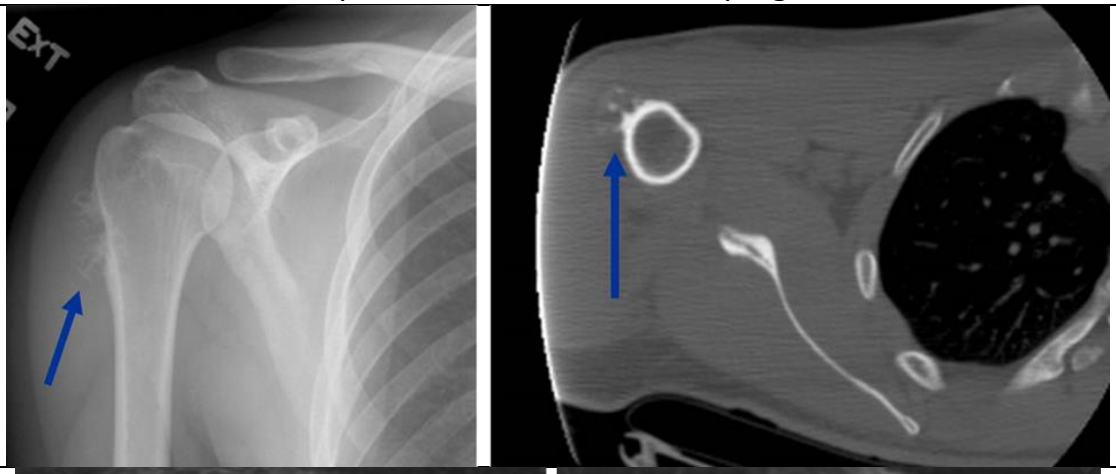
- is a benign exophytic osteochodral lesion which has an appearance similar to an osteochondroma,
- is typically seen in the hands and feet.
- BPOPs are continuous with the underlying cortex, but usually without continuation of the medulla
- wide based bony growth projecting into the soft tissues
- often lacks the characteristic orientation away from the nearby physis seen with osteochondromas.

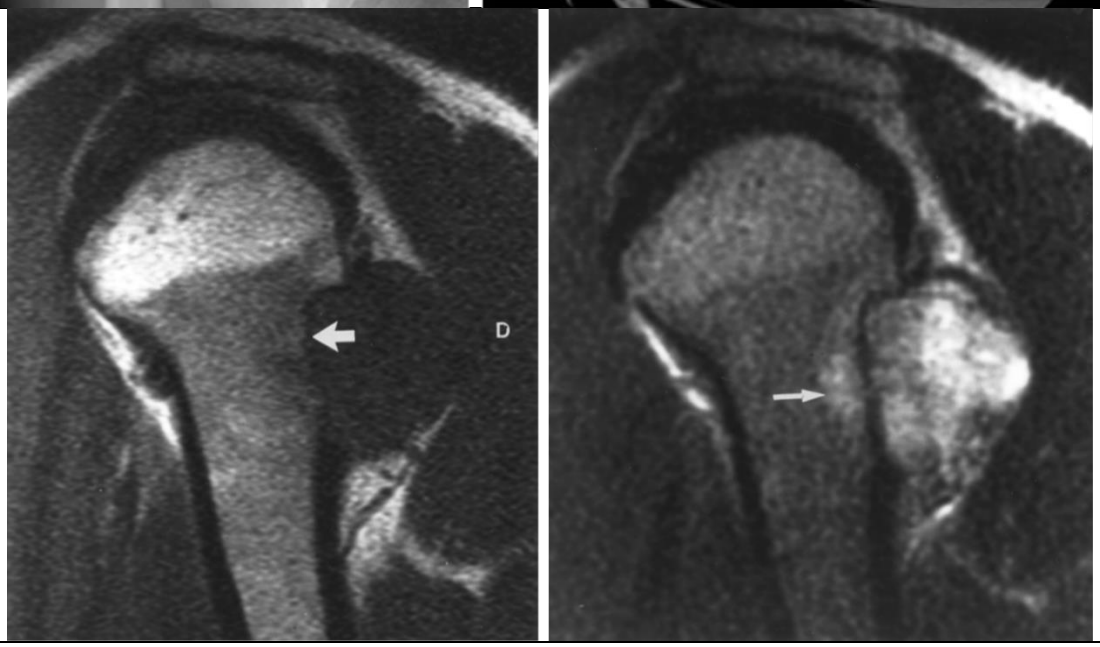
3) Juxtacortical ABC

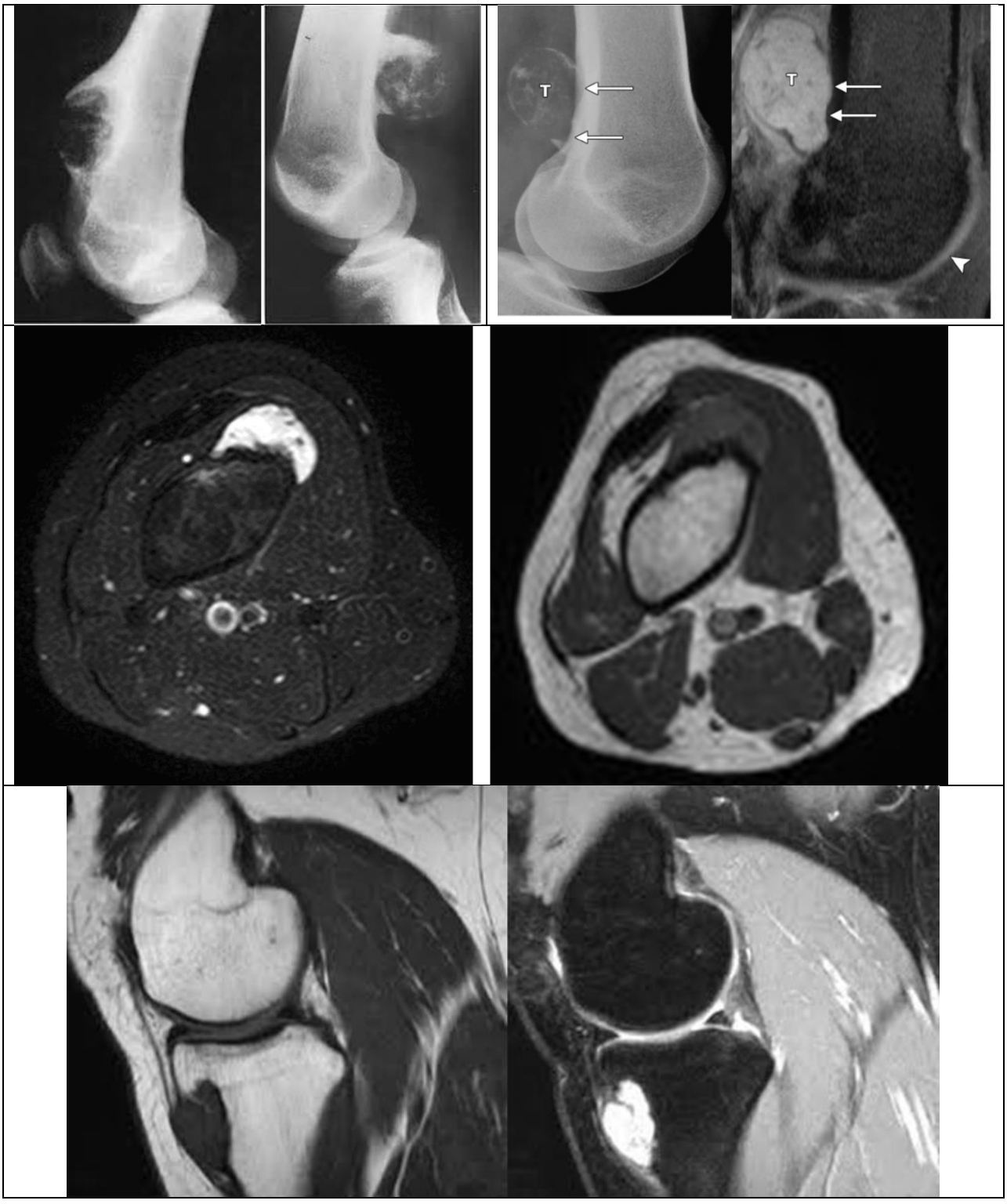


4) Juxta-Cortical Chordoma

- Uncommon
- Benign cartilagenous tumor
- Age: middle age < 30y
- Arise from periosteum surface of bones
- Long or short bones
- Most common sites: Proximal humerus and distal femur
- Metaphysis or shaft
- Size < 6cm
- Radiolucent cortical based lesion + chondroid matrix
- Cortical saucerization / pressure erosions / scalloping



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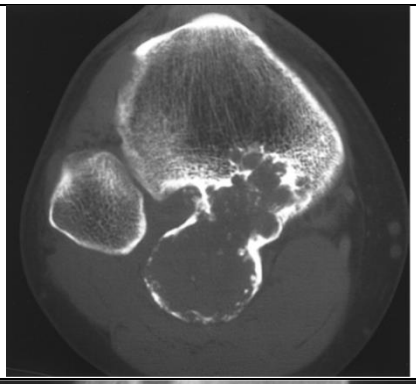
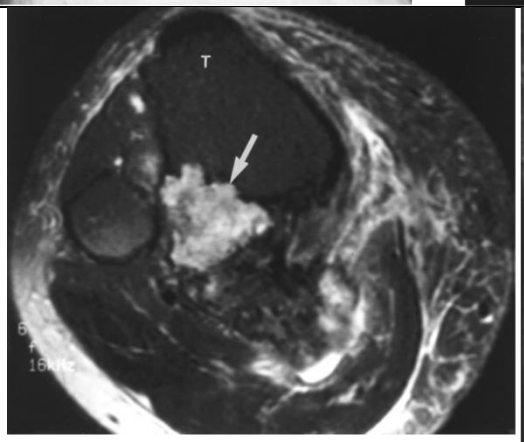
5) Juxtacortical / Periosteal Chondrosarcoma

- Malignant cartilagenous tumor
- Age > 20y (vs periosteal OS or chordoma)
- Size > 5cm (vs periosteal chordoma <5cm)
- Chondroid matrix calcification.
- Cortical erosions
- Medullary invasion.





III- Intra-Cortical Lesions

- **Osteoid Osteoma**
- **Adamantinoma**
- **Osteofibrous Dysplasia**
- **Cortical Desmoid**
- **Paget Disease**

1) Osteoid Osteoma

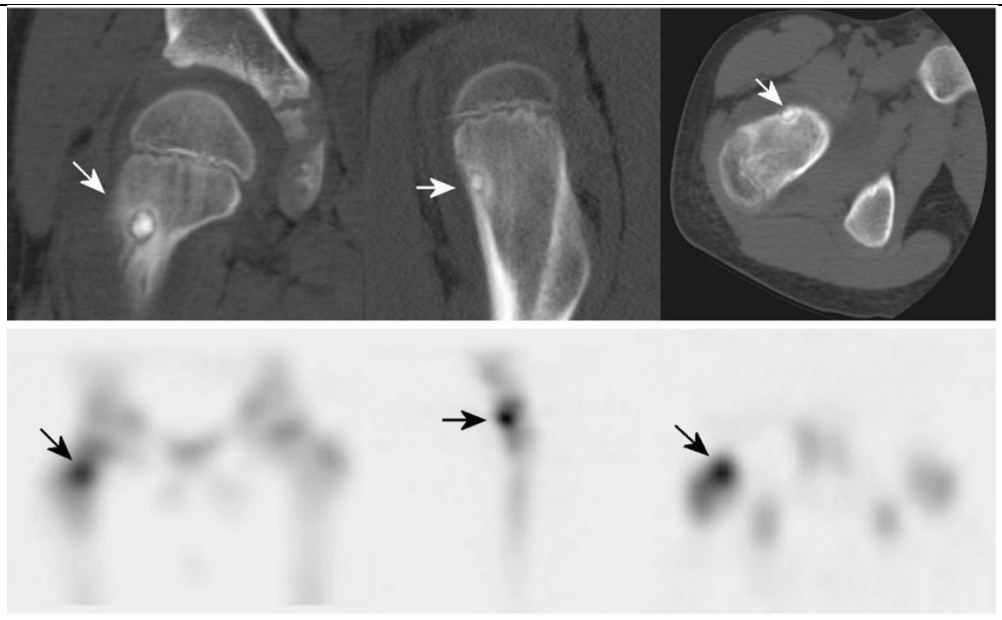
- The classic clinical presentation involves adolescent males with leg pain, worse at night, and relieved by salicylates.
- Age: Children, adolescents, and young adults, between the ages of 10 and 25.
- M>F

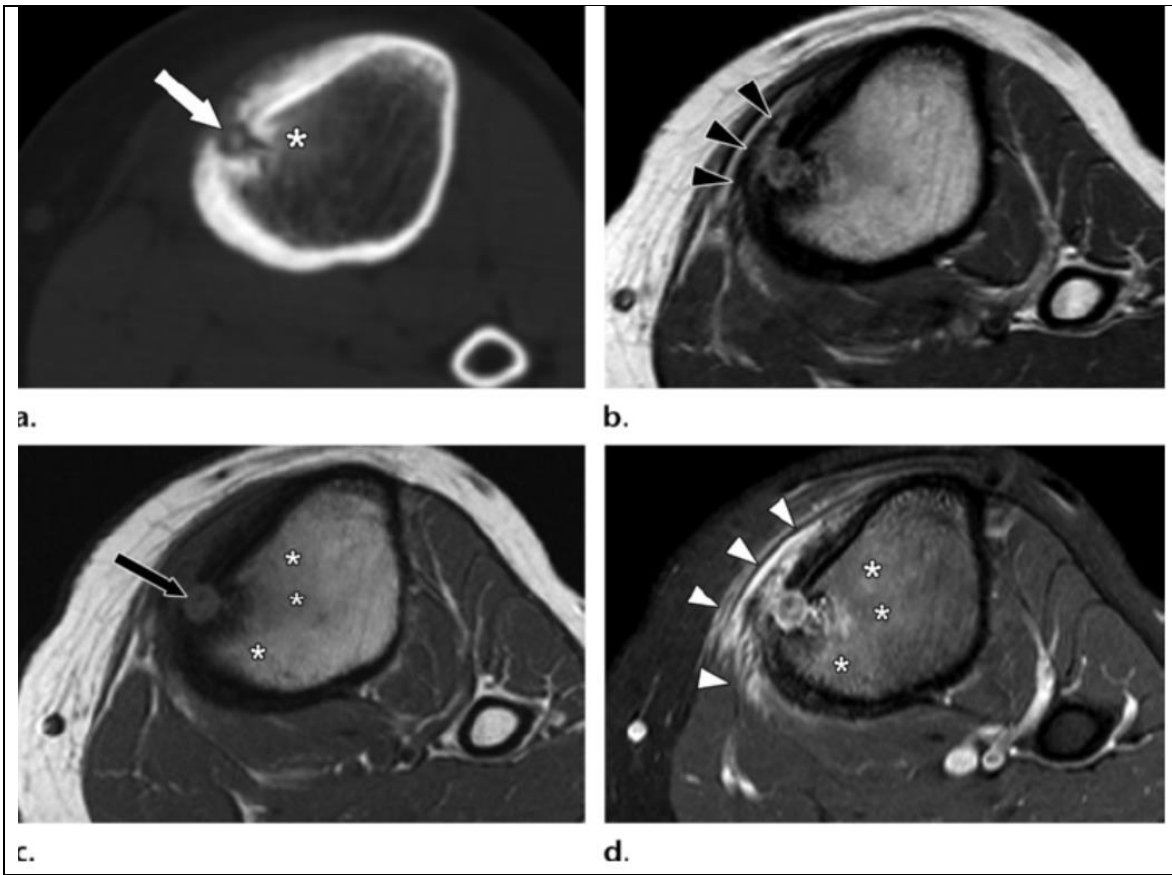
Location & distribution:

- Most common sites: Femur – Tibia
- Less common location: Spine, hands, or feet
- Least common locations : Skull, scapula, ribs, pelvis, mandible, and patella

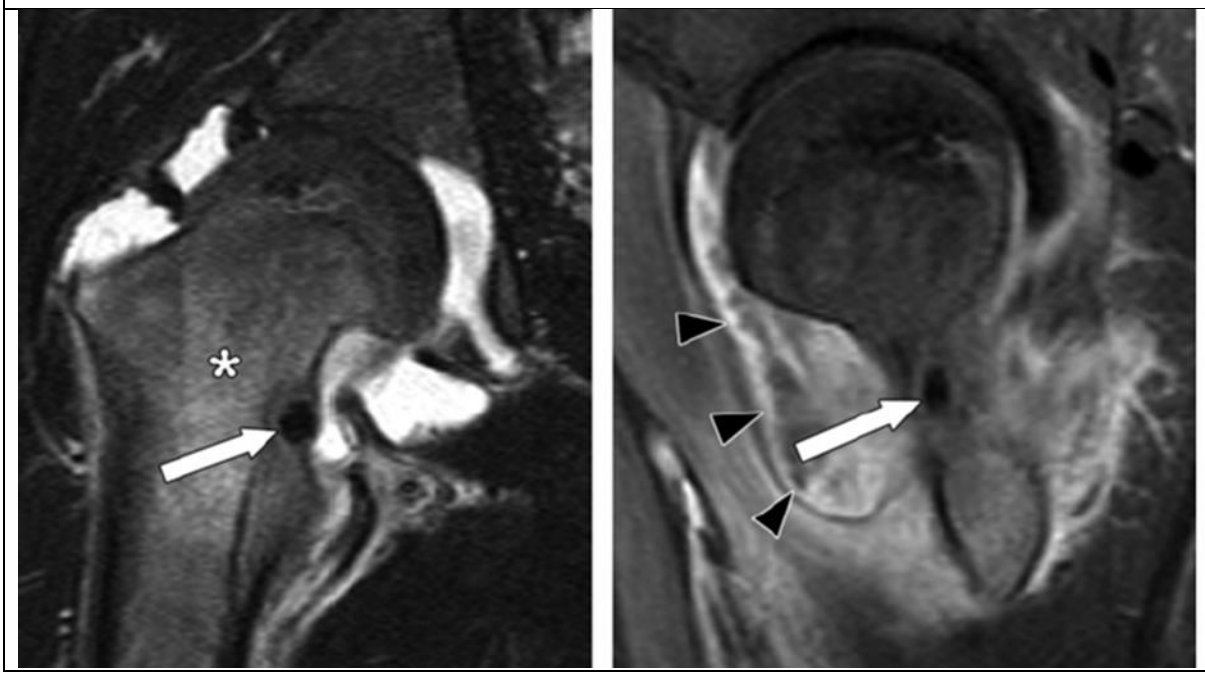
Radiological Findings:

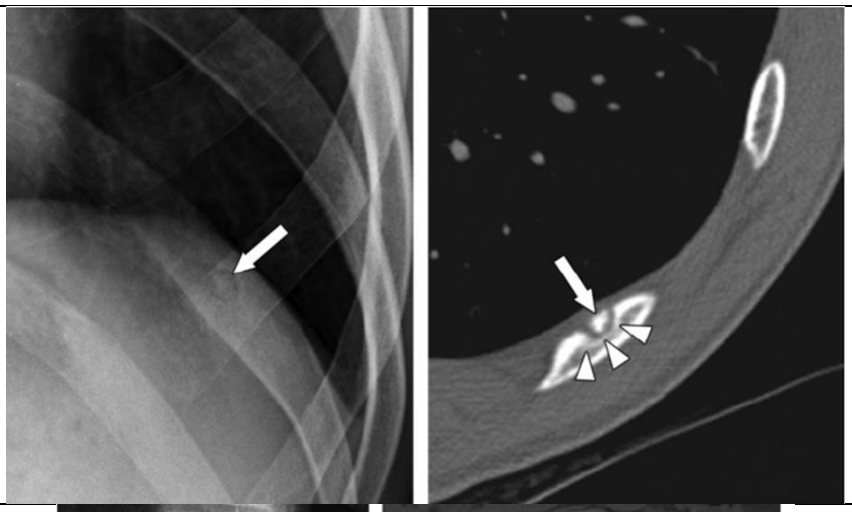
- Nidus: usually less than 1 cm in diameter,
    - CT: contains osteoid stroma of variable mineralization.
    - T1: low to intermediate
    - T2: variable signal intensity on T2, depending on the amount of mineralization present in the center of the nidus (Target sign)
- Surrounded by reactive bone sclerosis and cortical thickening.
- Bone marrow edema
- Soft tissue edema
- Joint effusion.

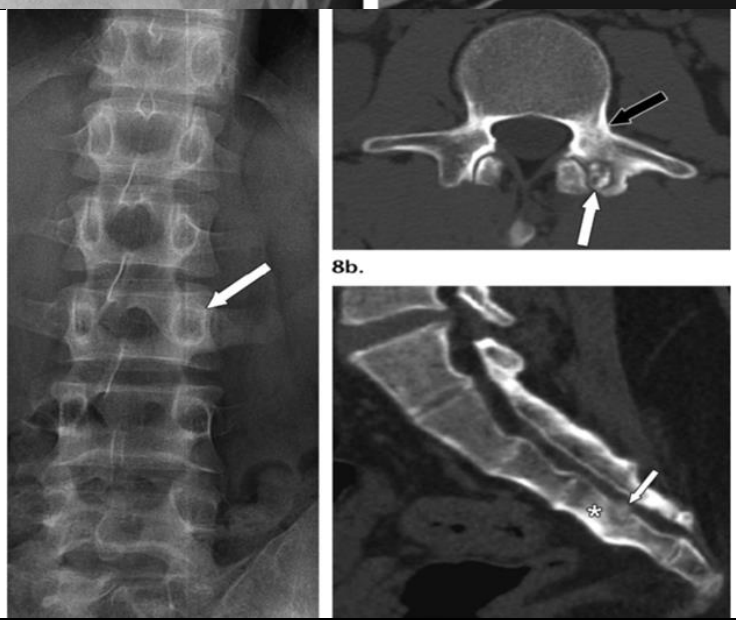




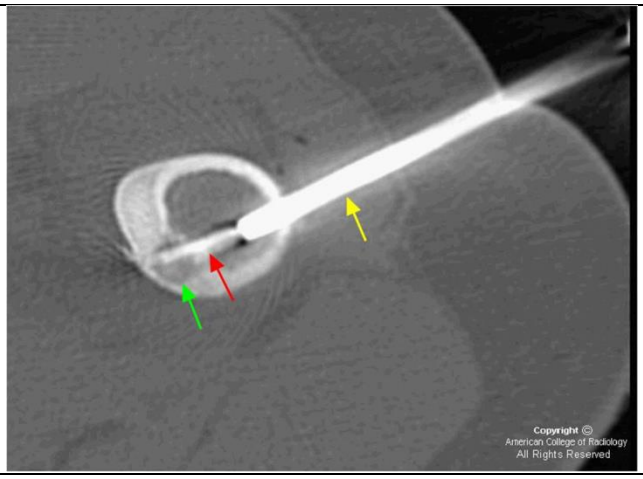
❖ Intra-articular Osteoid Osteoma







RFA for osteoid osteoma



2) Adamantinoma

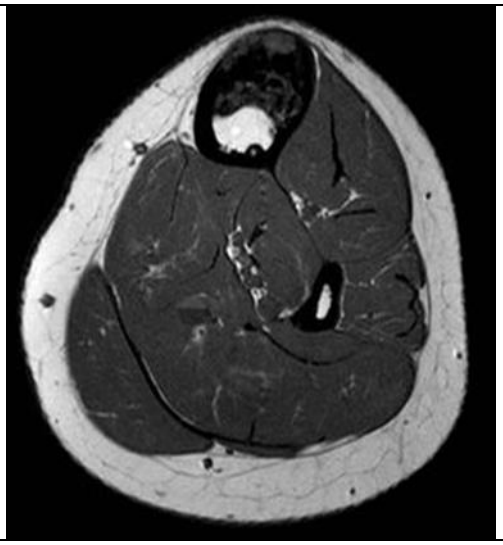
- Adamantinoma is a very rare primary malignant bone tumor of the long bones.
- Adamantinomas are mainly known for being locally aggressive and recurrent.

Location:

- Almost exclusively confined to ***anterior cortex of the tibial diaphysis.***

Imaging Findings:

- Multi-locular lucent bubbly expansile osteolytic bone lesion.
- This may be visualised as areas of lysis interspersed with areas of sclerosis.
- Lesions tend to have an eccentric epicenter and a lack of periosteal reaction.



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3) Osteofibrous Dysplasia

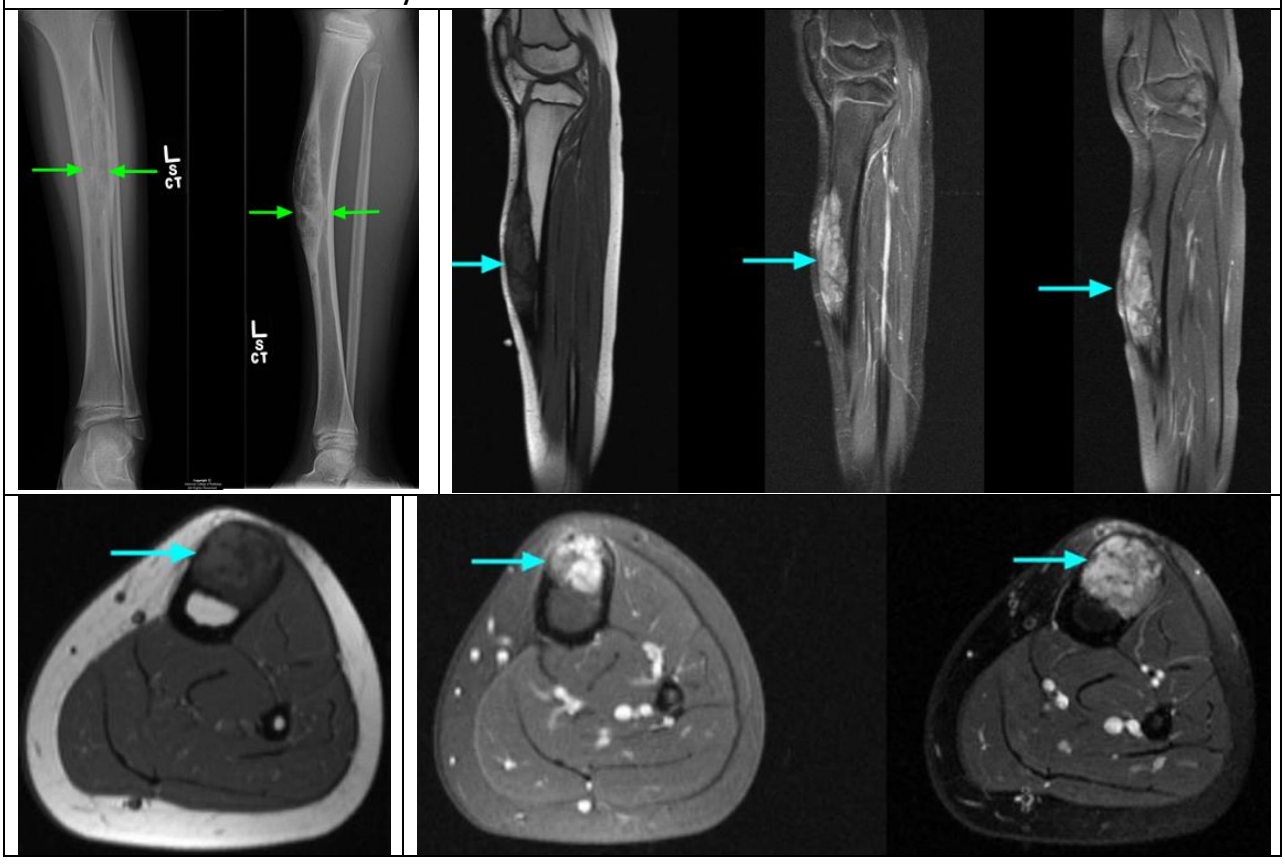
- Osteofibrous dysplasia is a rare, benign fibro-osseous lesion that occurs mostly in children under 10 years of age.

Location:

- ***The anterior cortex in the diaphysis of the tibia***
- associated lesions may be found in the fibula in a small percentage of cases.

Radiological Findings:

- Well-defined, cortically-based radiolucent lesions with sclerotic margins, and may have a characteristic "ground glass" appearance.
- T1: hypo- to isointense
- T2: hypo- to iso- to hyperintense
- T1+C: characteristically enhance.

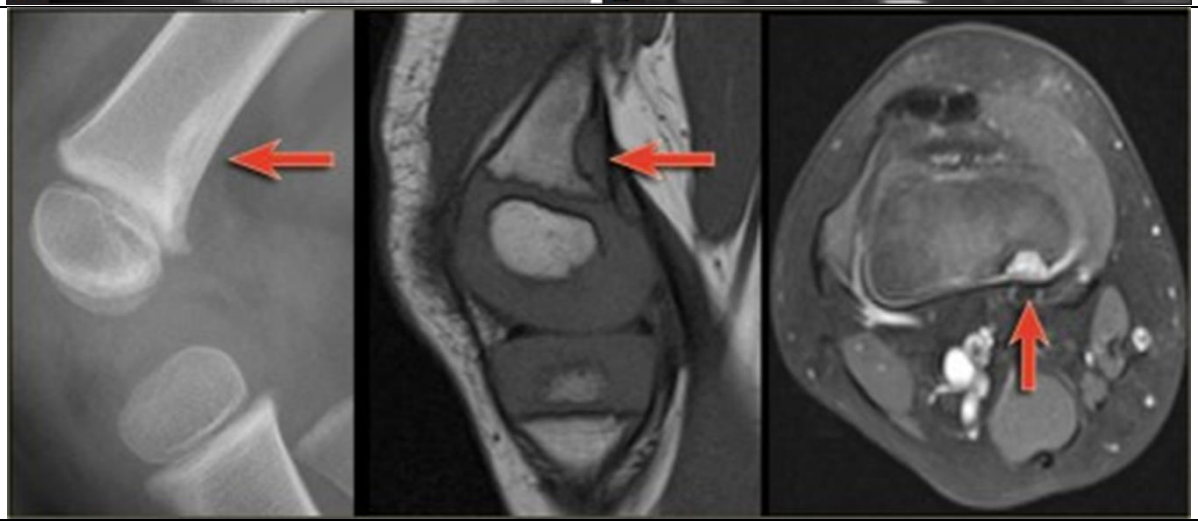


4) Cortical Desmoid

- = Cortical avulsion injury
- Don't touch lesion.
- Age: Teenage

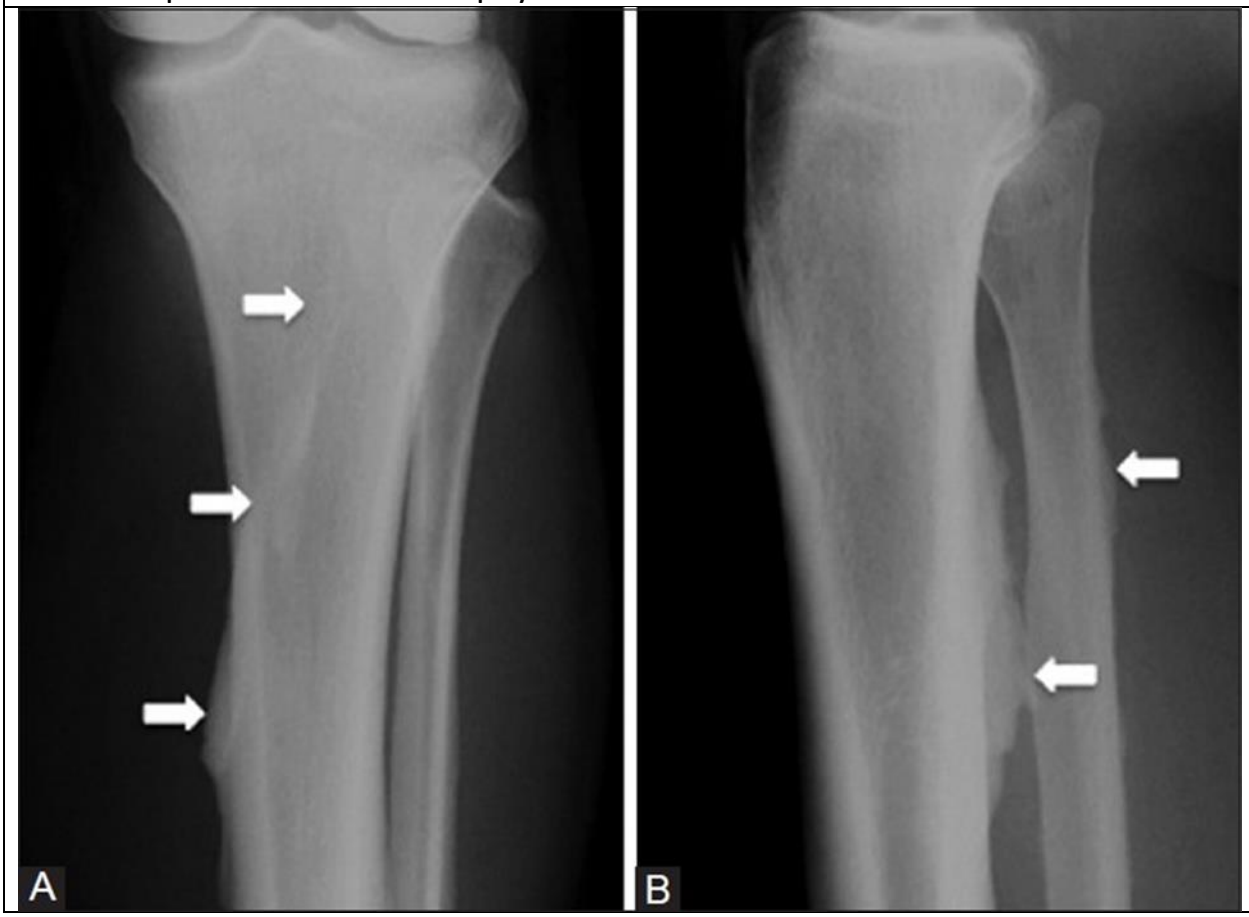
Location:

- ***Posteromedial aspect of distal femoral metaphysis at the attachment of adductor magnus tendon***



5) Soleal Line

- oblique linear cortical thickening
- along the posterior aspect of proximal tibia and fibula
- Corresponds to an enthesophyte from the attachment of the soleus.



IV- Eccentric / Cortical Based Lesions

1) Fibroxanthoma of bone

i. Non-ossifying Fibroma >2-3 cm
ii. Fibrous Cortical Defect < 2cm

- They are histologically the same
- is the most common benign bone tumor.
- can be left alone and will "heal" by age 30. They will become sclerotic and be termed ossified fibromas, and then likely will eventually heal completely and no longer be seen
- "Don't touch" lesion

Location:

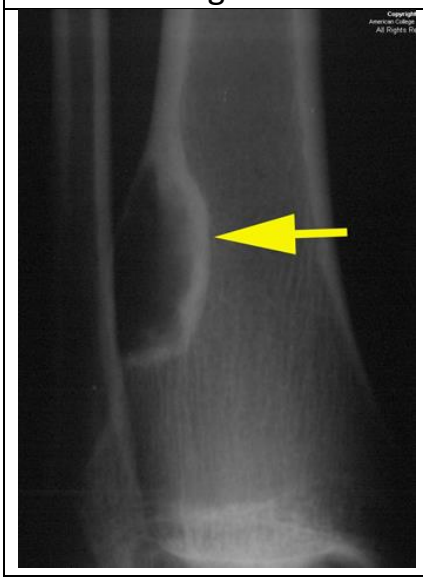
- Lower limb: most commonly occur in the tibia and femur.

Radiological Findings:

- A well-circumscribed osteolytic lesion
- Characteristic sclerotic band (osteoblastic rimming)
- Homogenous lesion matrix
- Ground-glass matrix

MRI:

- T1 : low signal
- T2 : iso - high signal
- T1 C+ (Gd) : typically shows enhancement
- Low signal rim



2) Chondromyxoid Fibroma

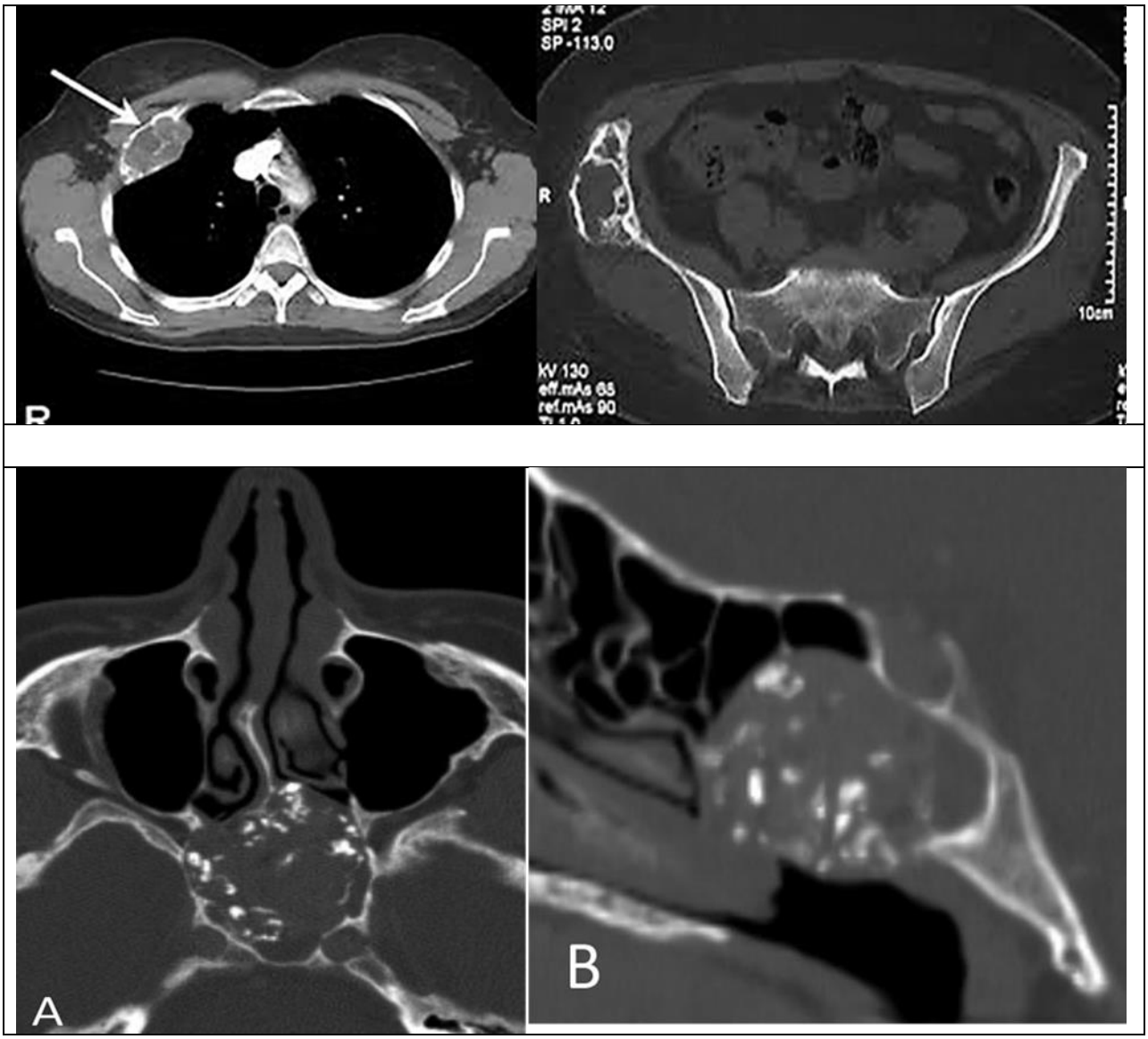
- Extremely rare
- Benign cartilaginous neoplasms that account for <1% of all bone tumours.

Location & Distribution:

- Meta-diphyseal of Long bones
- Eccenteric metaphysis
- Around knee (50%): Proximal tibia

Radiological Findings:

- Well-defined,
- Geographical osteolytic
- Expansile lesion
- Cortical thinning out
- Sclerotic rim


SPI 2
SP -113.0
R
10cm
kV 130
eff.mAs 65
ref.mAs 90
A
B

3) Osteoblastoma

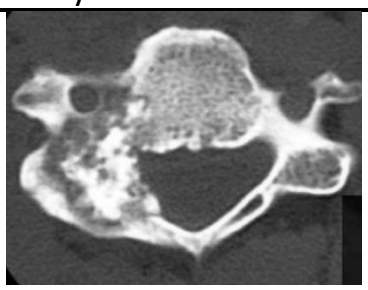
- Age = 2nd and 3rd decades
- M > F = 2:1.
- Histologically similar to osteoid osteoma

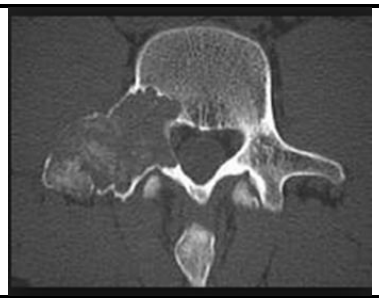
Location & Distribution:

- Spinal column: ~40% often involves the posterior column
- Long bones: Meta-diaphyseal region

Radiological findings:

- Well defined expansile lytic lesion
- >2cm (Giant osteoid osteom0
- Locally aggressive => Extend to the vertebral body
- Multifocal calcified / ossified matrix
- 2ry ABC





V- Medullary Lesions

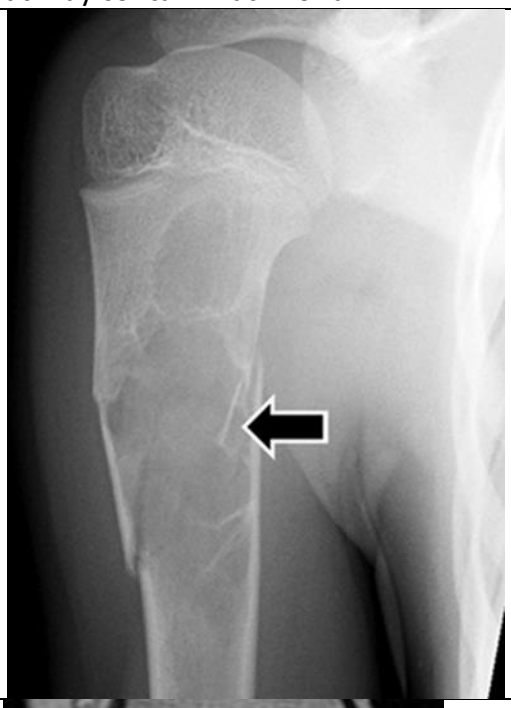
Well Defined	Ill Defined
Cyst = Unicameral bone cyst **C**yst = Aneurysmal Bone Cyst **C**yst = Intraosseous Ganglion Cyst **B**rown Tumor = Hyperparathyroidism **B**rodie's Abscess **B**one island = Enostosis **E**nchondroma **F**ibrous dysplasia **I**nfarct	**M**etastasis **MM** = Plasmacytoma **M**astocytosis **M**yelofibrosis **L**ymphoma **L**eukemia **LCH** = EG Osteosarcoma Ewing Sarcoma Chondrosarcoma Osteomyelitis

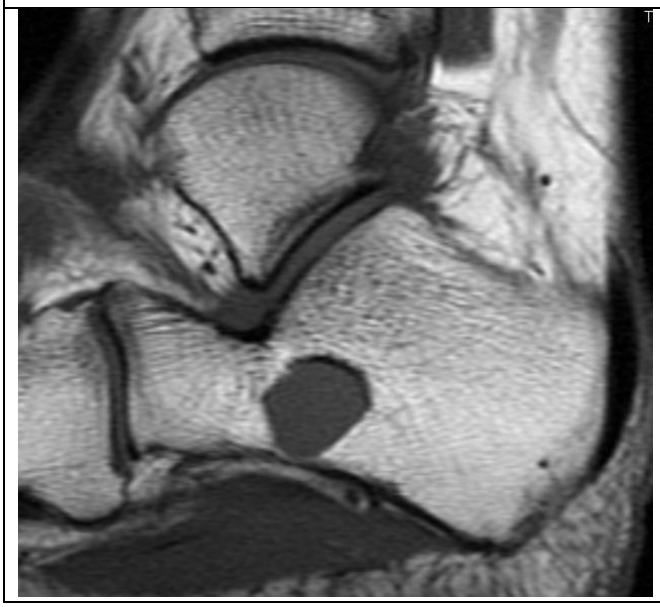
1) Unicameral Bone Cyst

- Age: children 5-15 years old.
- M>F.
- Location: Proximal humerus and femur account for 90% of all UBCs.
- The calcaneous is a common alternative, especially after 20 years of age.
- Cysts can rarely be multiloculated.
- They have a thin cyst wall and usually contain fluid, but may contain matrix or air.

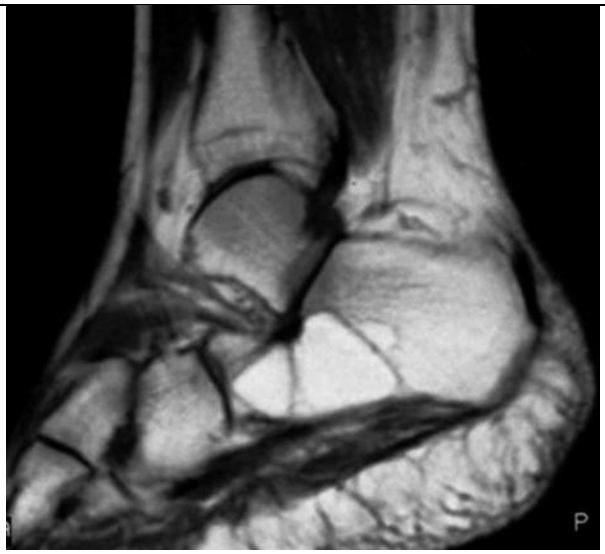
Radiographic findings:

- A well-demarcated geographic lesion
- Metaphysis but may migrate into the diaphysis with skeletal growth
- Thin sclerotic rim
- ***"Fallen fragment" sign***, due to displaced fracture fragment sinking to dependent portion of the cyst. (20% of cases).
- T1:Low signal
- T2: High signal
- **Non-aggressive features:**
    - Narrow zone of transition
    - Mild endosteal scalloping
    - Expansion of the overlying cortex
    - No cortical breakthrough unless fractured
    - No periosteal reaction
    - No soft tissue mass





2) Intra-osseous Lipoma

Calcaneal well defined osteolytic lesion Central calcification = Cockade sign		High T1 signal
		
Sagittal T1 reveal a peripheral rim of tissue (red arrowheads) that is isointense to subcutaneous fat	Sagittal fat suppressed proton density image shows homogeneous high signal intensity in the central portion of the lesion, consistent with fluid (F).	Sagittal fat suppressed, contrast enhanced T1 demonstrates thin peripheral enhancement of the cystic cavity (white arrowheads).

3) Aneurysmal Bone Cyst (ABC)

- Age= 10-30, with the majority (approximately 75%) occurring in patients less than 20 years of age.
- Patients usually present with acute pain that gets worse over a relatively short period of time.
- If the ABC is located in the spine, neurologic symptoms may be present due to compressive effects from the osseous expansion.

Two Types :

- **Primary lesions** account for the majority of ABCs (65%-99%) and are thought to occur as a result of trauma or other local alteration in the hemodynamics, which may be related to venous obstruction or AV fistula development.
- **Secondary lesions** account for 1%-35% of cases and arise in a preexisting bone lesion such as:
    - Giant cell tumor - Solitary bone cyst - Fibrous dysplasia
    - Non-ossifying fibroma - Metastasis
    - Osteoblastoma - Osteosarcoma

Location & Distribution:

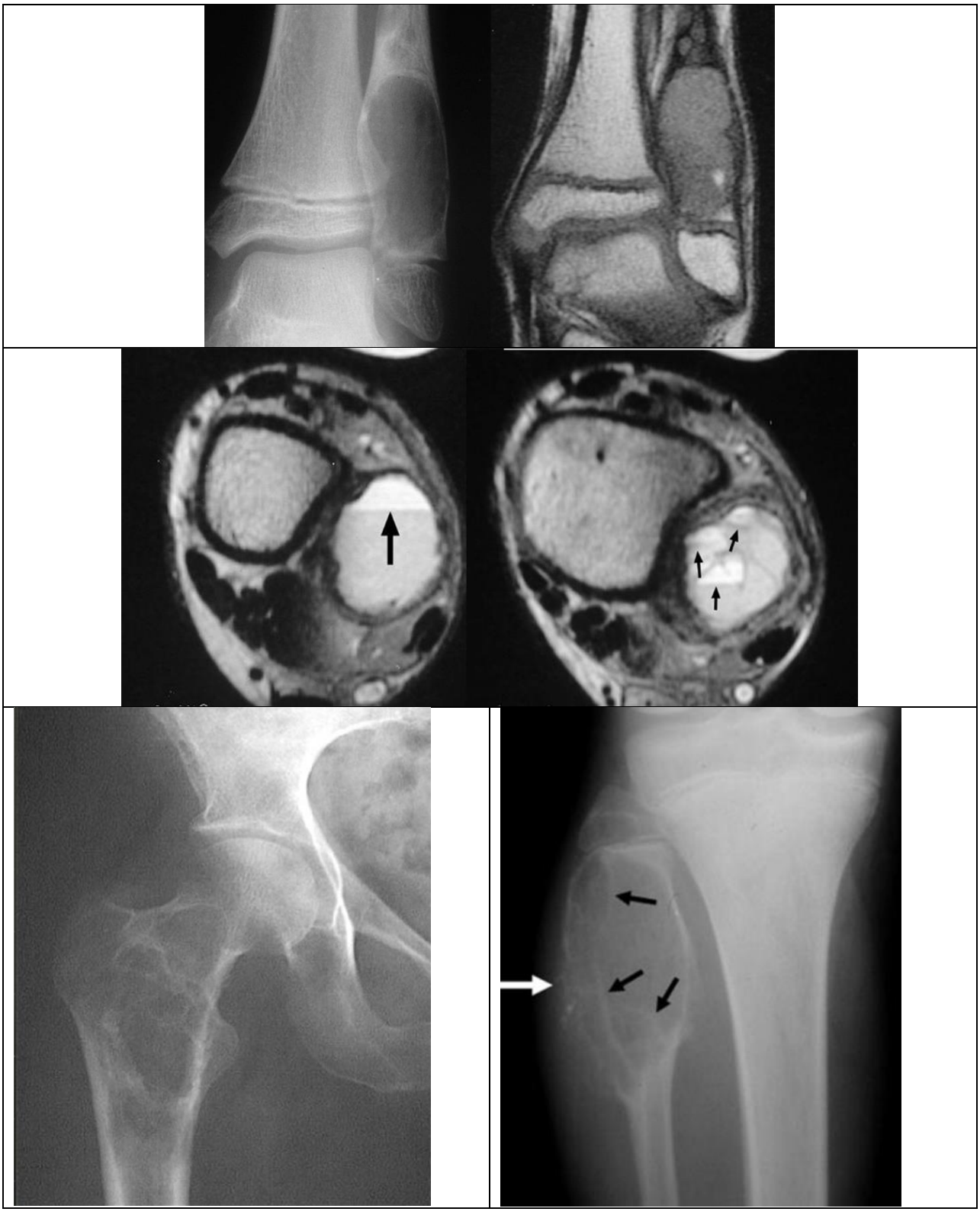
- Eccentric lesions that occur in the metaphyses of the long bones.
- LL > UL.
- They are also frequent in the spine, particularly the posterior elements.

Imaging Findings:

- Osteolytic, expansile lesions, sometimes with thin internal trabeculations.
- **Non-aggressive features:**
    - Narrow zone of transition
    - Mild endosteal scalloping
    - Expansion of the overlying cortex
    - No cortical breakthrough unless fractured
    - No periosteal reaction
    - No soft tissue mass
- These lesions usually do not cross the physis.

MRI:

- Multilocular cystic lesion
- Varying signal intensities, representing different types of fluid and stages of blood products, often resulting in fluid/fluid levels.
- A thin, well-defined rim of low signal intensity surrounding the lesion.



4) Enchondroma

- Common benign medullary cartilaginous neoplasm

Location & Distribution:

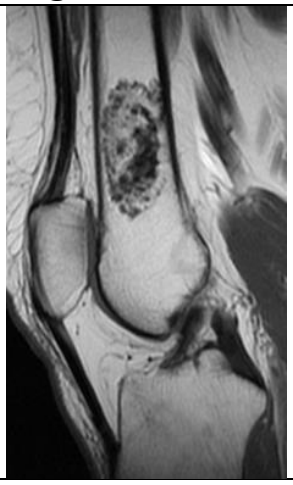
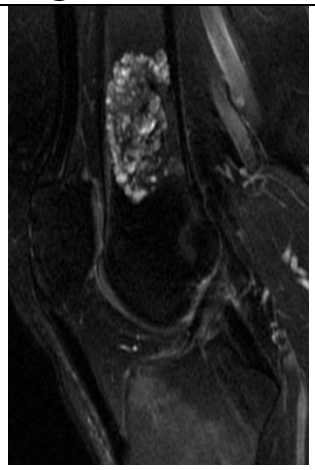
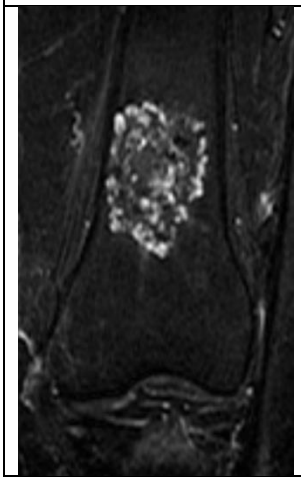
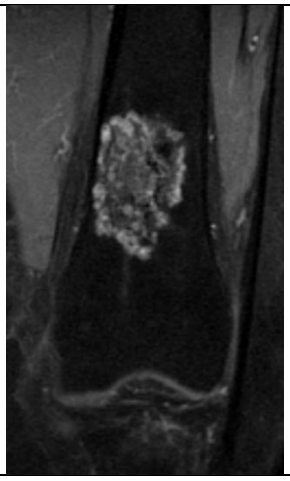
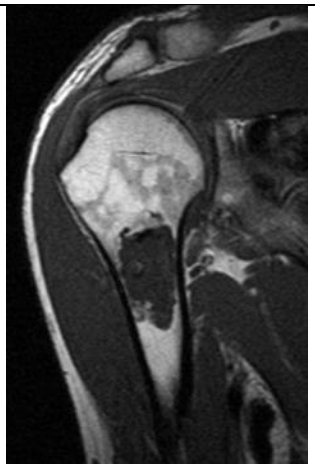
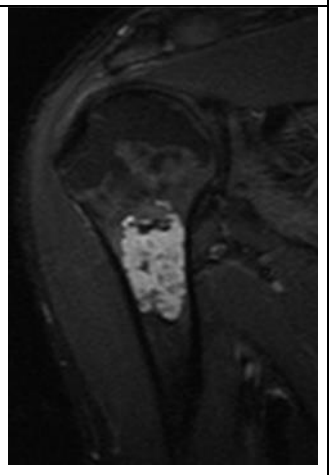
- Small tubular bones of the hands and feet: 50%
- large tubular bones, e.g. femur, tibia, humerus
- In the appendicular skeleton, enchondroma must be differentiated from chondrosarcoma.

Radiological Findings:

- Small 1-2 cm lytic lesions
- ***Characteristic rings and arcs pattern of chondroid calcification***
- **Non-aggressive features:**
    - Narrow zone of transition
    - Mild endosteal scalloping
    - Expansion of the overlying cortex may be present
    - No cortical breakthrough unless fractured
    - No periosteal reaction
    - No soft tissue mass

MRI:

- T1: intermediate to low-signal
- T2
    - Typically of background intense high signal
    - Focal regions of signal drop out where calcification present
    - No bone marrow or soft tissue oedema
- T1 C+
    - Enhancement is variable, and may be seen both peripherally or of translesional septae
    - similar pattern of enhancement may be seen in chondrosarcomas

X-ray AP	X-ray Lateral	Sagittal T1	Sagittal STIR
			
Coronal STIR	**Coronal T1+C**	**Coronal T1**	**Coronal STIR**
			

❖ Ollier disease

- is a non-hereditary, sporadic, skeletal disorder characterised by multiple enchondromas principally located in the metaphyseal regions

Associations

- There is an increased risk of chondrosarcoma occurring later in life. The risk has been reported to be up to 25-30% at 40 years
- There is an increased risk of developing gliomas, pancreatic and juvenile granulosa cell tumours of the ovary

❖ Maffucci Syndrome

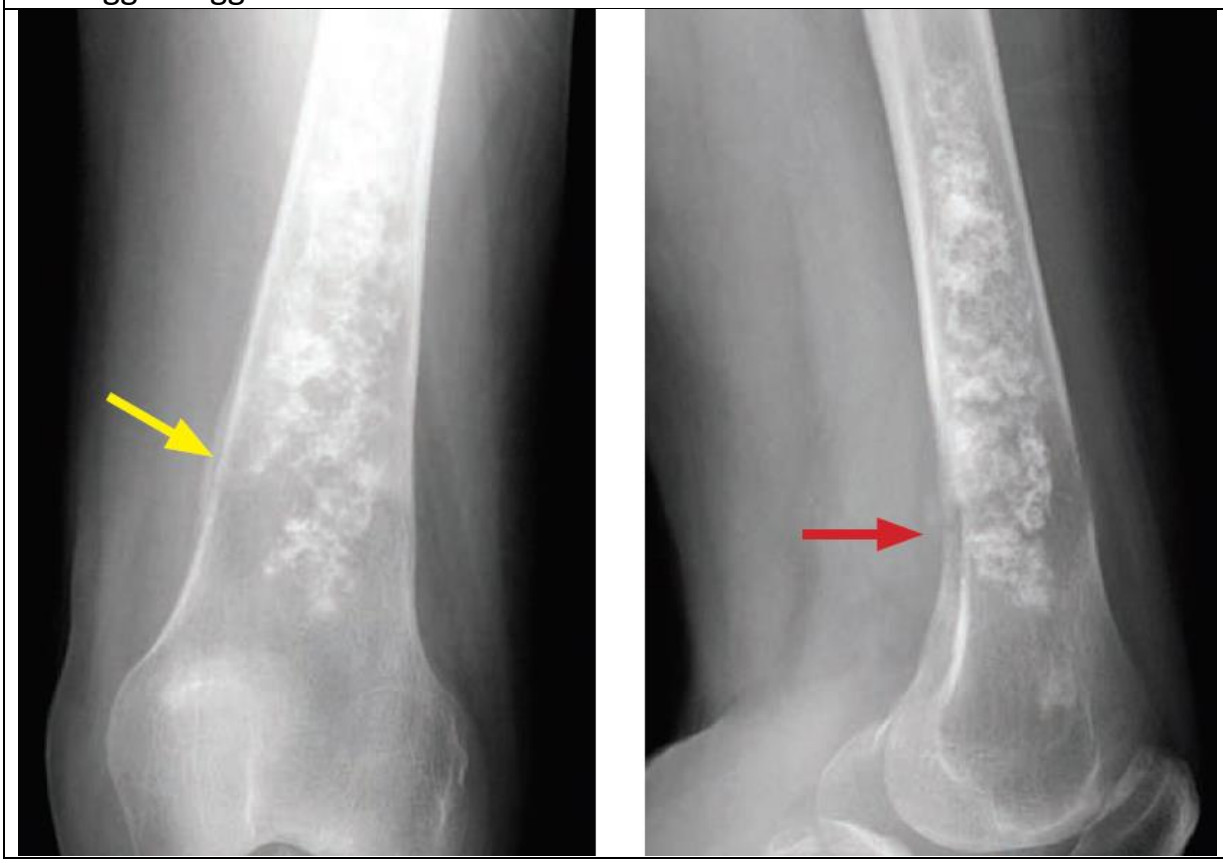
- is a congenital nonhereditary mesodermal dysplasia characterised by multiple enchondromas with soft-tissue venous malformations (haemangiomas).

❖ Enchondroma vs Low Grade Chondrosarcoma

- **Patient age**
  - Enchondromas commonly appear in young adults
  - Chondrosarcomas tend to appear in middle-aged patients
- **Pain**
  - Chondrosarcomas almost always present with pain
  - Enchondromas are painless unless they cause a pathological fracture
- **Location**
  - Hands and feet => uncommon locations for chondrosarcoma
  - Flat bones => rare location for enchondroma
- **Size**
  - Lesion size over 5-6 cm favours chondrosarcomas
  - Progression of lesion on serial radiograph suspicious for chondrosarcoma
- **Pattern of calcifications:**
  - Not reliable sign
- **Margins:**
  - Poorly defined margins cannot be used as a feature of differentiation.
- **Deep endosteal scalloping** involving > 2/3 of cortical thickness
  - 90% of chondrosarcomas
  - 10% of enchondromas
- **Cortical breach**
  - 88% of long bone chondrosarcomas
  - 8% of enchondromas
- **Abnormal bone marrow signal:**
  - Chondrosarcoma
  - Not seen in enchondroma
- **Soft tissue mass beyond bone**
  - Chondrosarcoma
  - Not seen in enchondroma
- **Increased uptake on bone scan**
  - 82% of chondrosarcomas
  - 21% of enchondromas

Chondrosarcoma secondary to enchondroma

- An intramedullary lesion with ring and arc chondroid calcifications.
- Periosteal reaction (yellow arrow) and cortical disruption (red arrow)
- Suggest aggressive behavior.

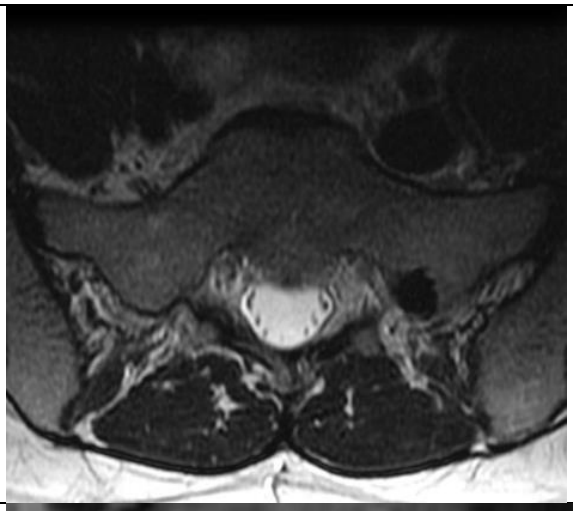


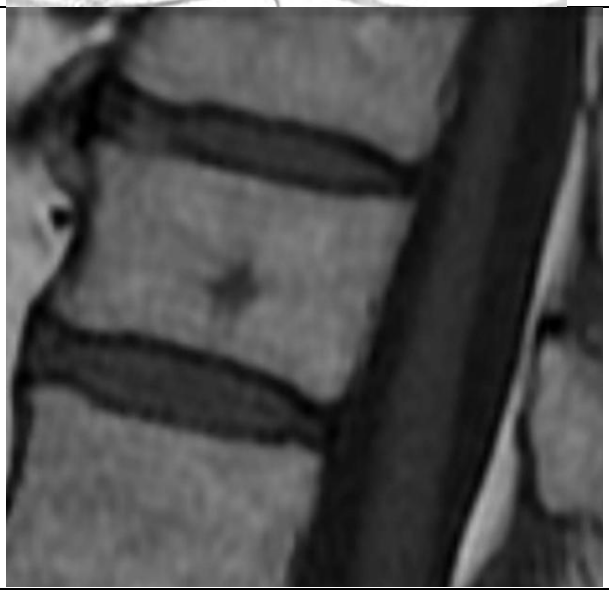
5) Bone island = Enostosis

- is an extremely common incidental finding.
- is only clinically significant in that it may rarely be difficult to differentiate from an osteoblastic metastasis, osteoid osteoma, or a low-grade osteosarcoma.
- Bone scan of bone island is usually normal.
- "don't touch" lesion.

Imaging Findings:

- A small round or oval foci of dense bone within the medullary space
- The appearance of radiating spicules - "thorny radiation" or "fingers" - at the margins that blend with the surrounding trabeculae is classic.
- MRI: Low signal intensity on all sequences





6) Bone Infarct

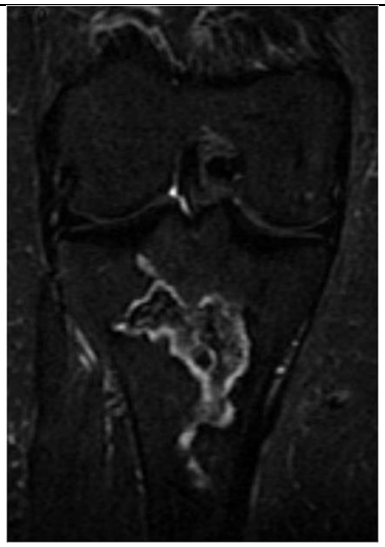
- Osteonecrosis within the metaphysis or diaphysis of a bone

Aetiology

- Trauma
- Caisson disease
- Haemoglobinopathies, e.g. Sickle cell disease
- Radiotherapy
- Connective tissue disorders
- Renal transplantation
- Corticosteroid excess (both endogenous and exogenous)
- Pancreatitis
- Gout
- Gaucher disease
- Alcohol

Radiological Findings:

- Well defined geographical medullary metadiaphyseal area
- Central area is similar to bone marrow signal
- Serpiginous borders
    - T1: serpiginous peripheral low signal
    - ***T2: Double-line sign:***
        - Hyperintense inner ring of granulation tissue
        - Hypointense outer ring of sclerosis

T1	STIR
	

Fibrous Dysplasia

- Fibrous dysplasia (FD) is a benign tumour-like congenital process, manifested as a defect in osteoblastic differentiation and maturation, with progressive replacement of normal bone with immature woven bone.

- Age: children and young adults,
- ~ 75% of patients presenting before the age of 30 years.

4 Subtypes:

- **Monoostotic** : single bone
- **Polyostotic** : multiple bones
- **Craniofacial** fibrous dysplasia : skull and facial bones alone
- **Cherubism** : mandible and maxilla alone (not true fibrous dysplasia)

Associations:

- **Mazabraud Syndrome**
- **McCune-Albright Syndrome**

Plain film:

- Ground-glass opacities
- May be completely lucent (cystic) or sclerotic
- Well circumscribed lesions

Pelvis + ribs

- Ribs are the most common site of monostotic fibrous dysplasia. Fibrous dysplasia is the most common cause of a benign expansile lesion of a rib (see rib lesions)
- Bubbly cystic lesions
- Fusiform enlargement of ribs
- Protrusio acetabuli

Extremities

- May lead to premature fusion of growth plates leading to short stature
- Bowing deformities
- Shepherd's crook deformity of femoral neck
- Discrepant limb length
- Looser zones

CT:

- Ground-glass opacities : 56 %
- Homogeneously sclerotic : 23 %
- Cystic : 21 %
- Well-defined borders
- Expansion of bone, with intact overlying bone
- Endosteal scalloping may be seen

MRI:

T1 : heterogeneous signal, usually intermediate

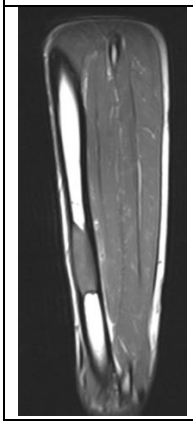
T2 : heterogeneous signal, usually low, but may have regions of higher signal

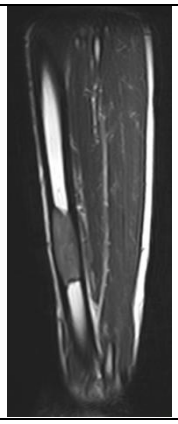
T1 C+ (Gd) : heterogeneous contrast enhancement

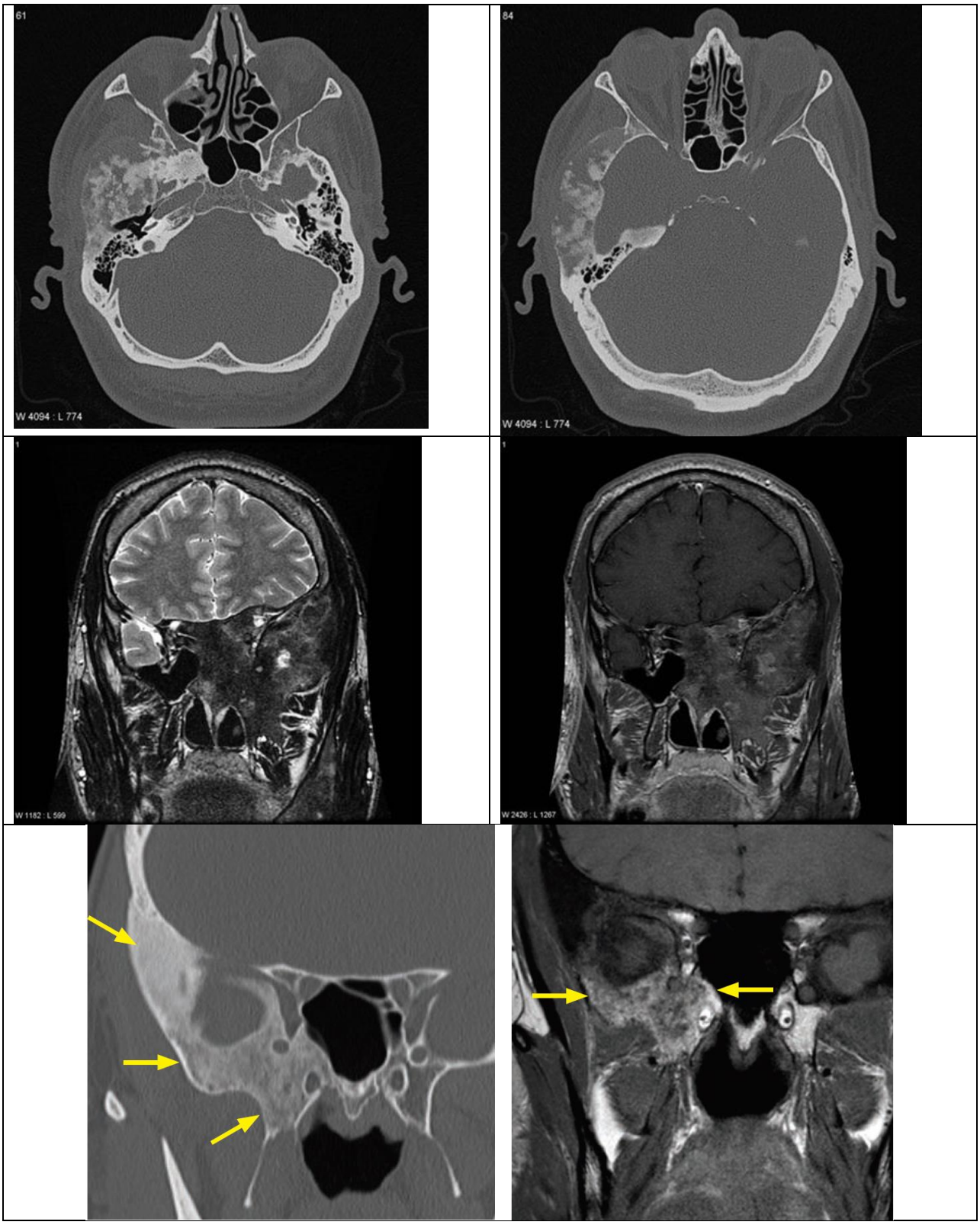
T1: Intermediate

T2: low

+C: Mild enh






61
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84
W 4094 : L 774
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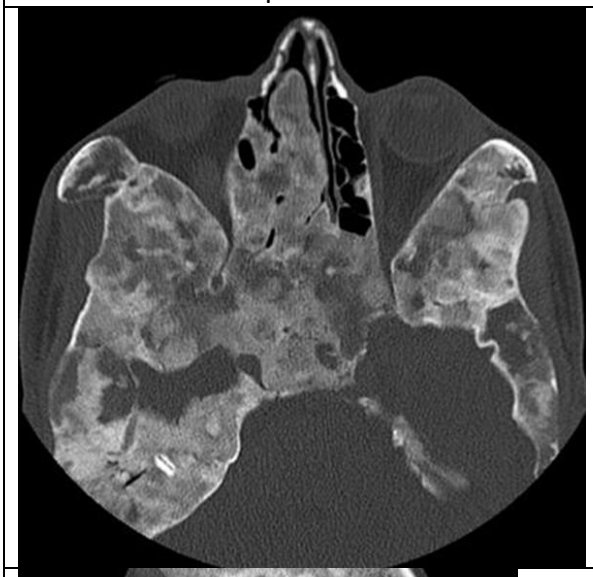
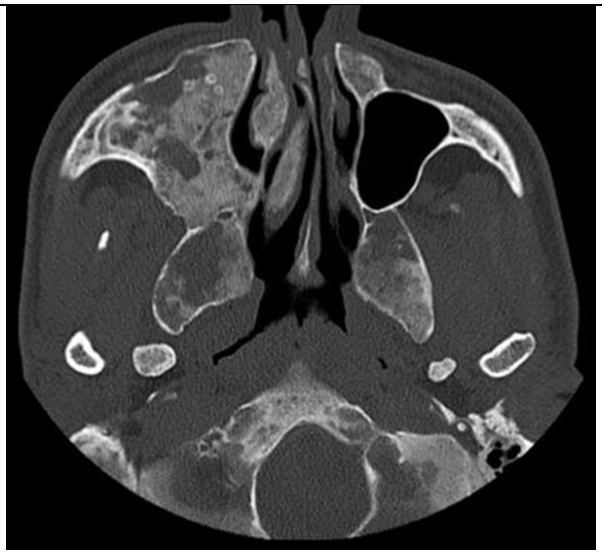
❖Craniofacial Fibrous Dysplasia

- Craniofacial fibrous dysplasia is one of 4 types of fibrous dysplasia and is characterized by involvement of the skull and facial bones.
- Leontiasis ossea has been used synonymously with craniofacial fibrous dysplasia.
- The craniofacial bones are affected in up to 50% of polyostotic cases.
- Occasionally it is seen in the setting of McCune-Albright syndrome

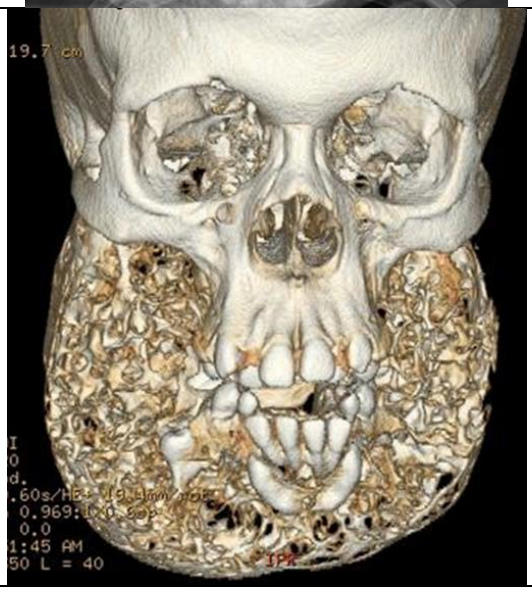
Radiological Findings:

- Blistering / bubbling cystic skull vault lesions
- Commonly cross sutures
- Sclerotic skull base
- Widened diploic space with displacement of outer table, inner table spared (this is in contrast to paget disease, in which case the inner table is involved)
- Obliteration of paranasal sinuses

❖Cherubism

- Bilateral expansile multiloculated cystic masses with symmetric involvement of mandible and maxilla with soap-bubble appearance



❖Mazabraud Syndrome

- Mazabraud syndrome is a rare entity characterized by the association of:
  - **Fibrous Dysplasia + Intramuscular Myxomas**

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❖McCune-Albright syndrome

Clinical triad of

- **Polyostotic fibrous dysplasia**
- **Endocrine dysfunction**
- **Abnormal skin pigmentation.**

Endocrine dysfunction

- Precocious puberty (onset before 8 years in females and 9.5 years in males) is a common finding.
- Pituitary : Acromegaly if growth hormone is hypersecreted
- Thyroid – hyperthyroidism: Failure to thrive - Poor muscle tone - Tachycardia
- Adrenals: Cushingoid features

Dermatologic findings:

- **Café-au-lait spots**
  - Sporadic (not autosomal dominant as NF-I)
  - Irregular flat areas of increased skin pigmentation
  - often on the trunk.
  - rarely cross the midline and often abruptly stop in the midline of the abdomen or spine

Osteosarcoma

- is the most common primary bone tumor in children and adolescents
- is a malignant tumor of connective tissue that produces osteoid matrix and variable amounts of cartilage matrix and fibrous tissue

❖ Subtypes

1) Conventional	**6) Small Cell**
2) Parosteal	**7) Low-grade Central**
3) Periosteal	**8) Secondary**
4) High-grade Surface	**9) Osteosarcomatosis**
5) Telangiectatic	**10) Extraskeletal**

1) Conventional Osteosarcoma

- 75% of all osteosarcomas
- Age: 15 and 25 years
- Rare younger than 6 or older than 60 years
- Male > Females 1.5–2:1

Location & distribution:

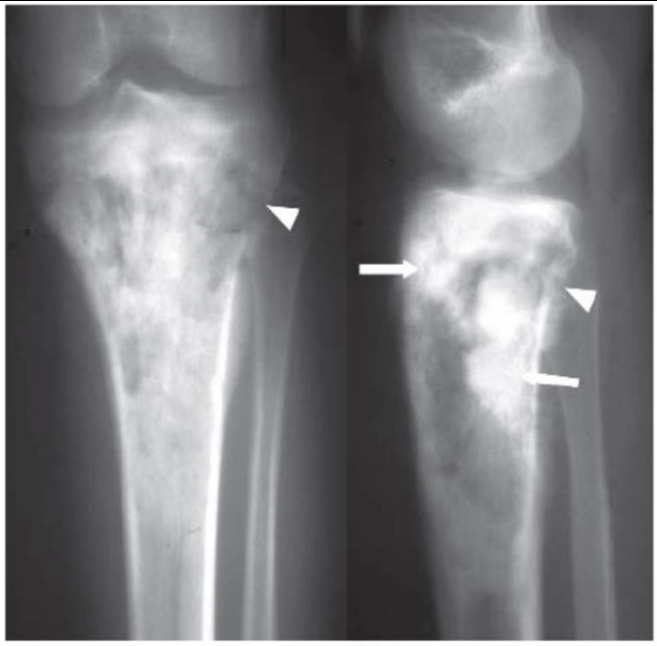
- 80% Long bones
  - 80% around knee
  - 80% distal femur
  - 90% metaphyseal
  - 5%–10% diaphyseal
- Flat bones: Pelvis – scapula – clavicle – ribs
- Spine.

Role of Imaging => Tumor diagnoses & Staging:

- Extent of tumor within medulla
- Extra-osseous soft tissue extension
- Relation to vessels
- Evaluation of adjacent joint
- Detection of intra-medullary skip lesions

Radiological Findings:

- Mixed sclerotic and lytic bone lesion
- Soft tissue mass (80%)
- Periosteal reaction (80%):
  - Codman triangle
  - Lamination
  - Perpendicular (“sunburst”, “hair on end”)
- Osteoid matrix “fluffy”/ “cloud-like” (90%)
- Extend across epiphyseal plate (75% - 90%)
- MRI/CT essential for staging and preoperative planning



Intramedullary osteosarcoma with osteoid matrix (arrows) and aggressive bone lysis (arrowheads)

Coronal STIR MR image and gross specimen of tibial intramedullary osteosarcoma show identical lesion extent (*)

Juxtacortical Osteosarcoma = Surface Osteosarcoma

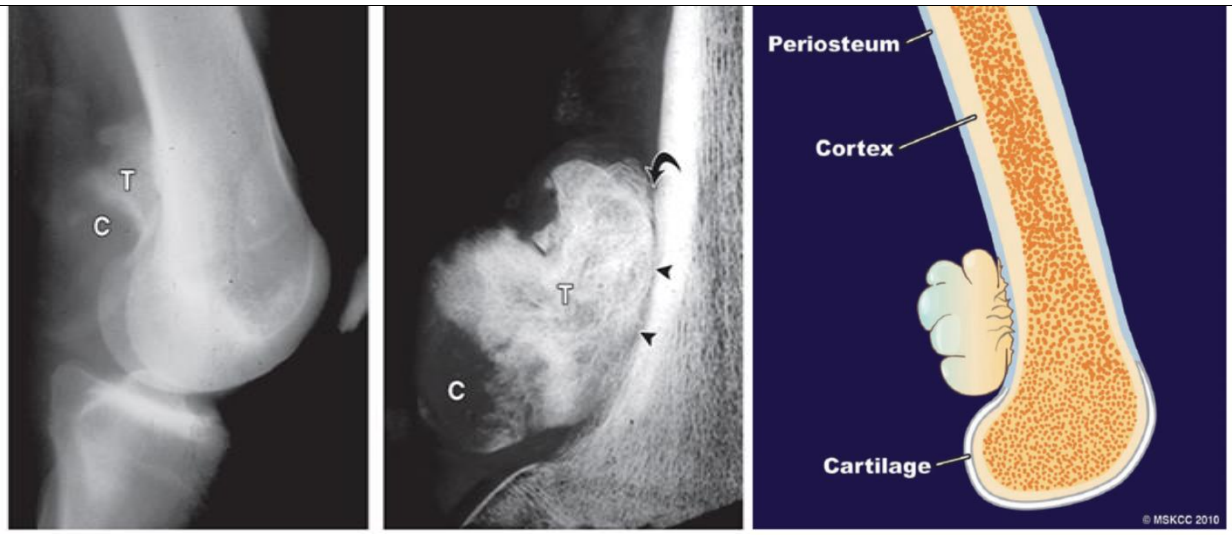
- **Parosteal (65%)**
- **Periosteal (25%)**
- **High grade surface (10%)**

2) Parosteal Osteosarcoma

- most common type of juxta- cortical OS
- 5% of all OS cases
- Age: 2nd to 4th decades of life
- Metaphyses of long bones
- Most common location: posterior aspect of the distal femur
- Prognosis is better than that for conventional OS, as the 5-year overall survival rate is 86%–91% for the former but 53%–61% for the latter

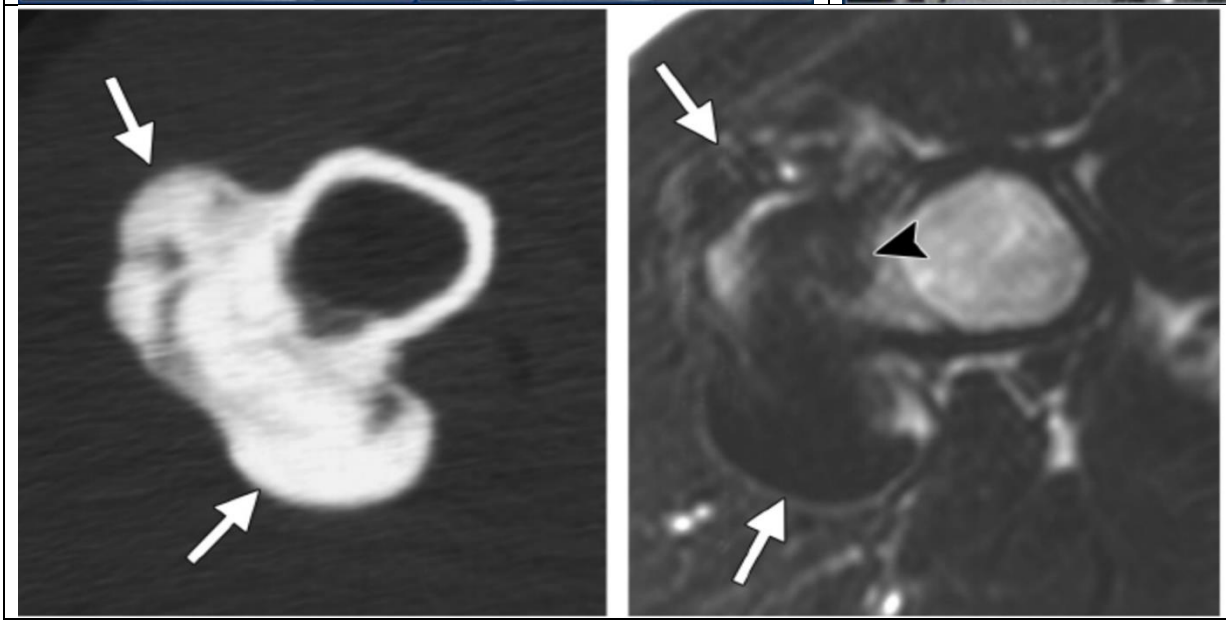
Radiological Findings:

- A lobulated and exophytic mass with central dense ossification adjacent to the bone
- A cleavage plane separating the tumor and adjacent normal cortex (the string sign)
- The tumor is attached to cortex by a broad pedicle.
- No aggressive periosteal reaction.
- Cortical thickening, due to focal expansion of the inner portion of the tumor and fusion with the cortex



MRI:

- The ossified tumor is predominantly low on T1- and T2-
- When there is an unmineralized soft-tissue mass larger than 1 cm3 or the lesion is predominantly high in T2 signal intensity, the tumor is more likely to be of high grade

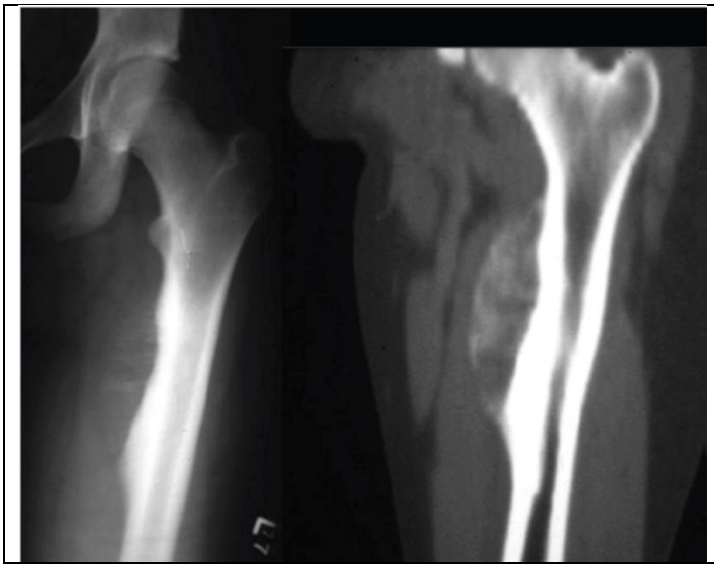


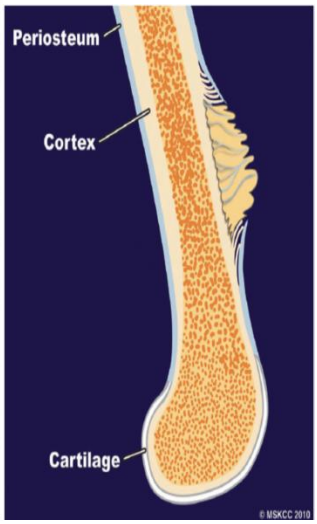
3) Periosteal Osteosarcoma

- 2nd most common type of juxtacortical OS (after paraosteal OS)
- 1.5% of all OS cases
- in the 2nd or 3rd decade of life,
- Diaphyses of long bones
- Most commonly the tibia
- The prognosis (83% 5-year survival rate) is better than that for conventional OS but worse than that for parosteal OS.

Radiographic findings

- A soft-tissue mass
- Periosteal reaction
- Cortical erosion
- Cortical thickening
- Rare intramedullary extension.
- Periosteal reaction often extends perpendicularly from the inner cortex to the outer margin of the tumor.



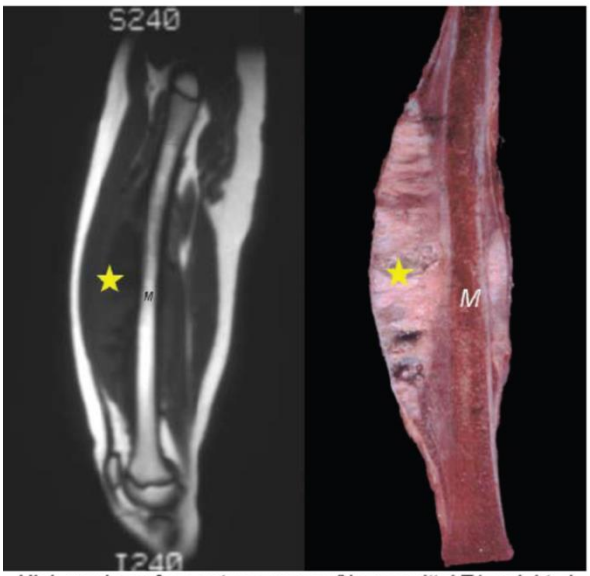


4) High-Grade Surface Osteosarcoma

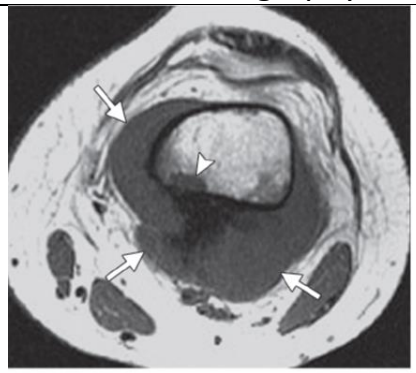
- is rare
- accounting for 0.4% of all OS cases
- Least common type of juxtacortical OS.
- 2nd and 3rd decades of life
- Diaphyses and metaphyses of long bones
- Femur being the most common site
- Large, ranging from 4.5 to 22 cm
- Prognosis considered worse than that for other types of juxtacortical OS and similar to that for conventional OS

Radiographic findings:

- Dense ossification and periosteal reaction
- Cortical erosion and thickening
- The rate of intramedullary invasion is variable 8% to 48% of cases
- Circumferential bone involvement can be more extensive in high-grade surface OS than in other forms of juxtacortical OS.
- When medullary invasion is a prominent feature, it may be difficult to distinguish this tumor from conventional OS with a large extraosseous component. However, to make the diagnosis of high- grade surface OS, the bulk of the lesion must be external to the bone at radiography.



High-grade surface osteosarcoma (*) on sagittal T1-weighted MR and sagittally sectioned gross specimen. Note the surface location and sparing of the medullary canal (M)



c.

Figure 16. High-grade surface OS in a 19-year-old woman. **(a)** Radiograph shows ossification *(O)* and periosteal reaction (arrows) within a tumor (arrowheads) along the surface of the distal femur. **(b)** Photograph of a coronal section of the gross specimen shows lifting of the periosteum (arrowheads) by the tumor *(T)*. *B* = biopsy defect. **(c)** Axial T1-weighted MR image shows that the tumor (arrows) surrounds the femur circumferentially and invades the medullary canal focally (arrowhead). Histologic analysis showed a diffusely high-grade neoplasm with intramedullary extension.

	Paraoesteal	Perioesteal	High grade surface
Incidence	1st	2nd	Rare
Age	2nd -4th	2nd -3rd	2nd -3rd
Location	Metaphysis Posterior femur	Diaphysis tibia	Meta+diaphysis Femur
Prognosis	> conventional	para<peri> conv	= conventional
Origin	Outer surface of fibrous layer of perioesteium	Inner germinocyte layer of perioesteium	Surface pf bone
Grade	Low	Intermediate	high
Imaging	Densely calcified matrix No periosteal reaction No Cortical thickening NO Medullary invasion	Chondroid matrix Periosteal reaction Evident cortical thickening	Circumferentional affection + medaullry inavsion

5) Telangiectatic Osteosarcoma

- 1.2%–7.0% of all OS
- 1st and 2nd decades of life
- Metaphyses of long bones,
- Femur being the most common site
- Prognosis for telangiectatic OS has substantially improved.
- The favorable response to chemotherapy may be related to the increased growth fraction of tumor cells compared with that in conventional OS, since most chemotherapeutic agents used for OS are cell cycle specific

Radiological Findings:

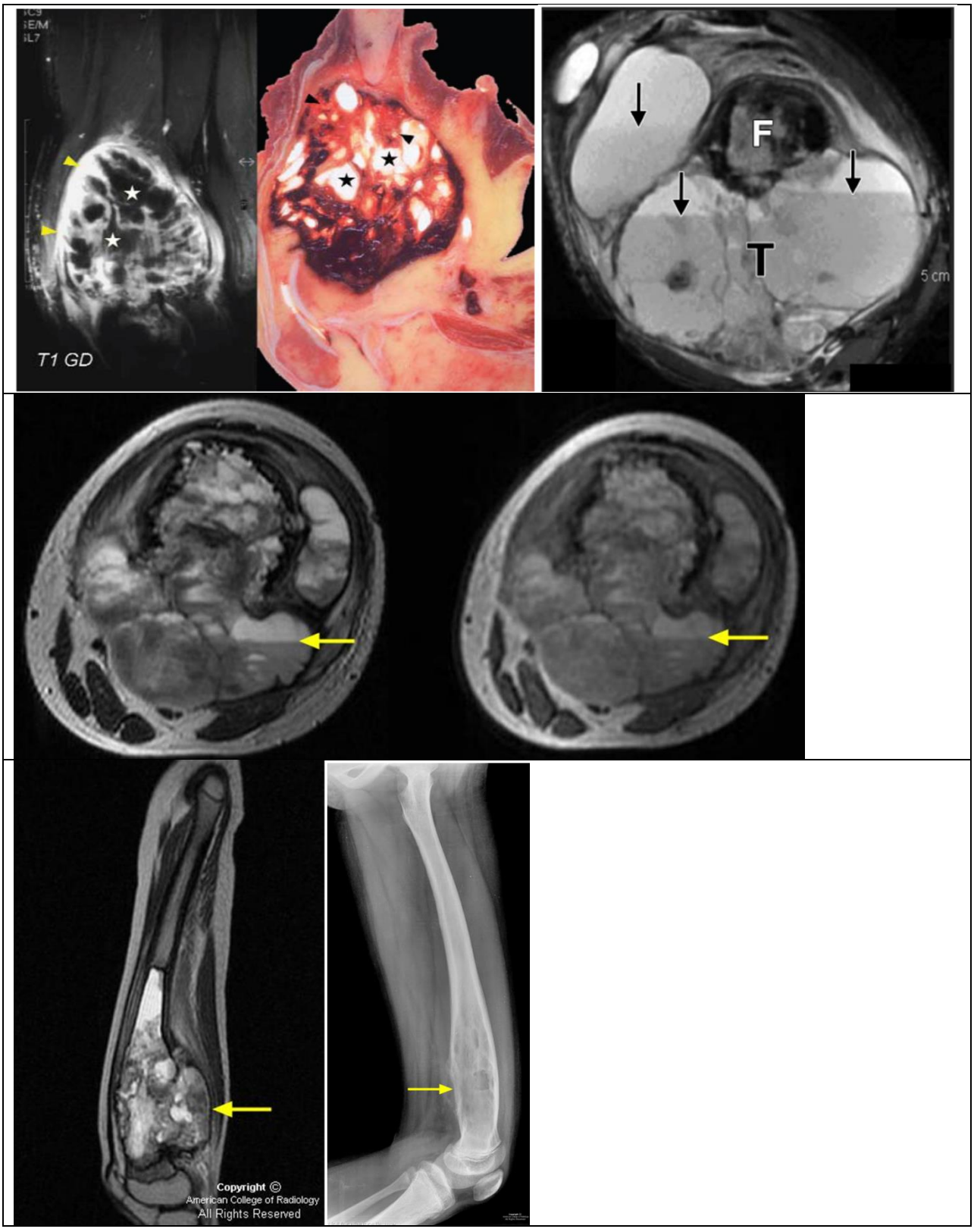
- Asymmetric expansion,
- Geographic lysis of bone,
- Aggressive growth pattern with cortical destruction and minimal peripheral sclerosis
- Pathologic fracture is also frequent (43%–61% of cases)

Common CT features:

- A soft-tissue mass with attenuation lower than that of muscle,
- Osteoid matrix mineralization, fluid levels, and thick peripheral and nodular septal enhancement
- The enhancing thick rim and septa correspond to viable high-grade sarcomatous tissue in hemorrhagic or necrotic spaces;
- Osteoid matrix mineralization
    - Occurs only in the viable neoplastic tissue in these areas
    - Is often subtle on radiographs and of limited extent because viable tumor cells make up only a small amount of the lesion compared with the volume of cystic spaces.
    - more easily detected at CT (85%) than at radiography (58%) than that of muscle.

MRI

- Hemorrhage (high signal intensity on T1-and variable signal intensity on T2)
- Fluid levels are frequently identified


T1 GD
F
T
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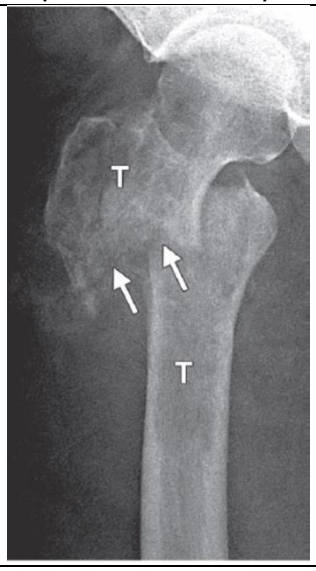
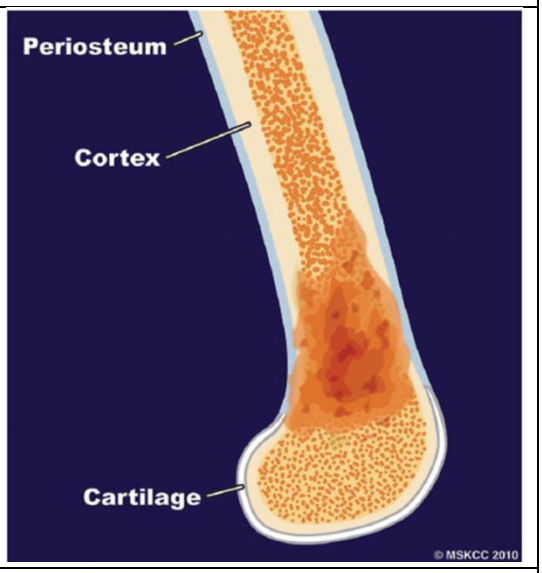
6) Small Cell Osteosarcoma

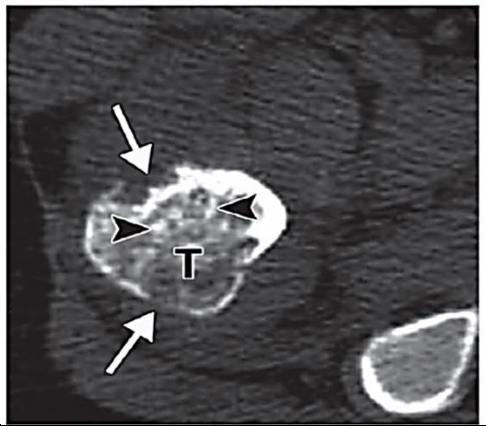
- 1% of all OS cases
- in the 2nd and 3rd decades of life.
- located in the metaphyseal region of long bones
- most frequently involve the femur, but a minority (14%) are purely diaphyseal
- Prognosis slightly less favorable than those with conventional OS and Ewing sarcoma.

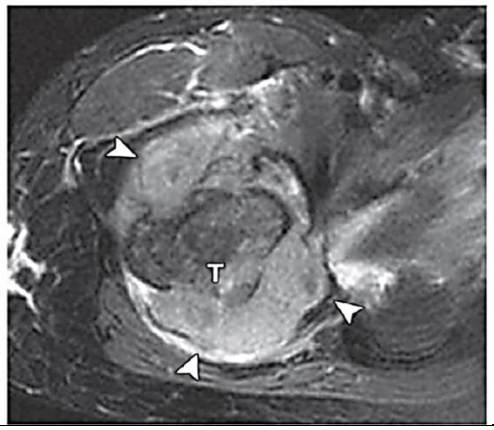
Radiographic features

- Permeative lytic bone destruction
- a soft-tissue mass,
- Periosteal reaction (>50% of cases)
- Calcification in the intramedullary cavity or an associated extraosseous soft-tissue mass (>50% of cases)







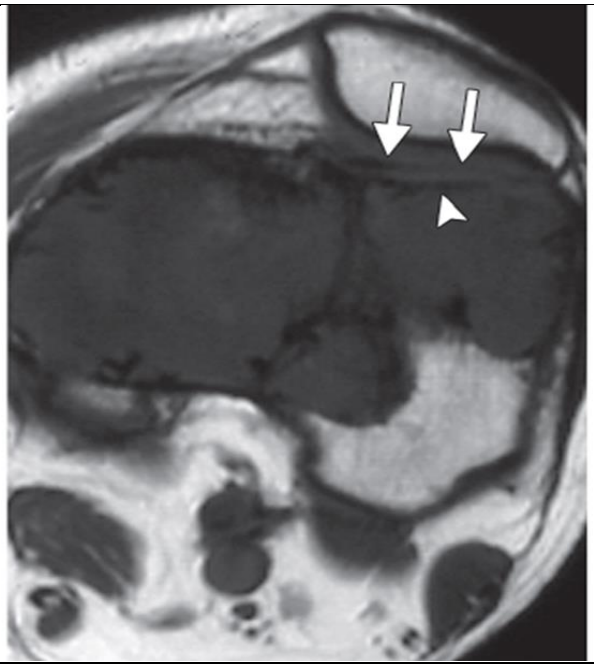


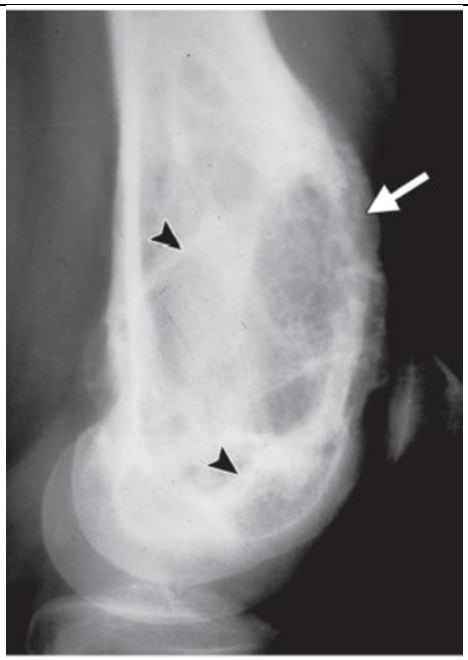
7) Low-Grade Central Osteosarcoma

- uncommon subtype (<1% of OS cases)
- 3rd or 4th decade of life,
- it commonly occurs within the medullary canal of the distal femur and proximal tibia
- Prognosis better than that for patients with conventional OS,
- the potential for dedifferentiation, local recurrence, and metastatic spread

Radiological Findings:

- Expansile lytic bone destruction with coarsely thick or thin incomplete trabeculation (61% of cases)
- A dense sclerotic pattern is less common (<30% of cases)
- Cortical disruption and soft-tissue extension are common at imaging
- Variable rates of periosteal reaction (22%–50%) at radiography are also reported.





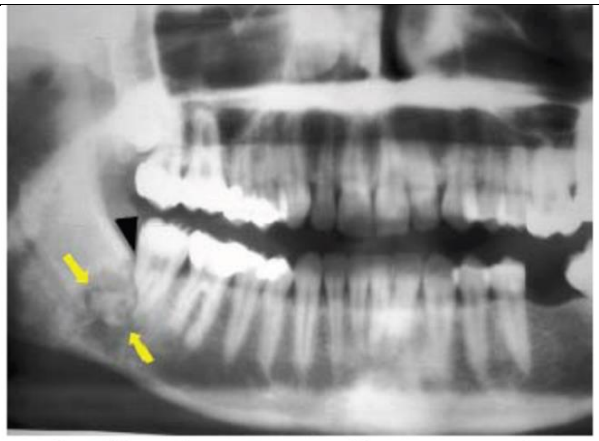
8) Secondary Osteosarcoma

- About half of osteosarcoma over age 50 are secondary, 67% over age 60

- Paget disease (67% - 90%)
- Radiation induced (6% - 22%)
- Osteonecrosis
- Others - fibrous dysplasia, prosthesis, osteogenesis imperfecta, chronic osteomyelitis, retinoblastoma

❖ Gnathic Osteosarcoma

- 6% of all osteosarcomas
- Patients are usually older
- Lesions are usually lower grade
- About half are chondroblastic
- Prognosis is better – don't tend to metastasize but locally invasion



Gnathic osteosarcoma with an aggressive mixed lytic and sclerotic (arrows) lesion destroying the alveolar ridge (arrowhead)

9) Multifocal Osteosarcoma = Osteosarcomatosis:

- Rare
- Classified into types in 1969 by Amstutz:
  - Type 1-Synchronous, young patients < 18 years of age
  - Type 2-Synchronous, adults
  - Type 3-Metachronous
- Type 3 likely represents metastatic disease)
- Types 1 and 2 usually demonstrate a radiologically dominant lesion

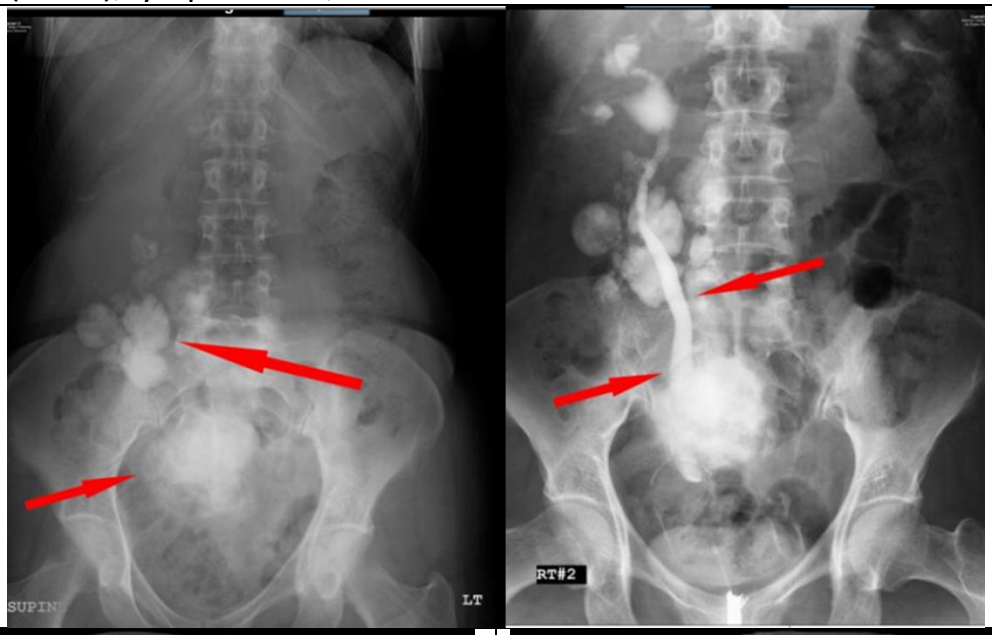
Osteosarcomatosis with multifocal areas of metaphyseal sclerosis (*) with primary dominant sclerotic focus in the tibia (*)

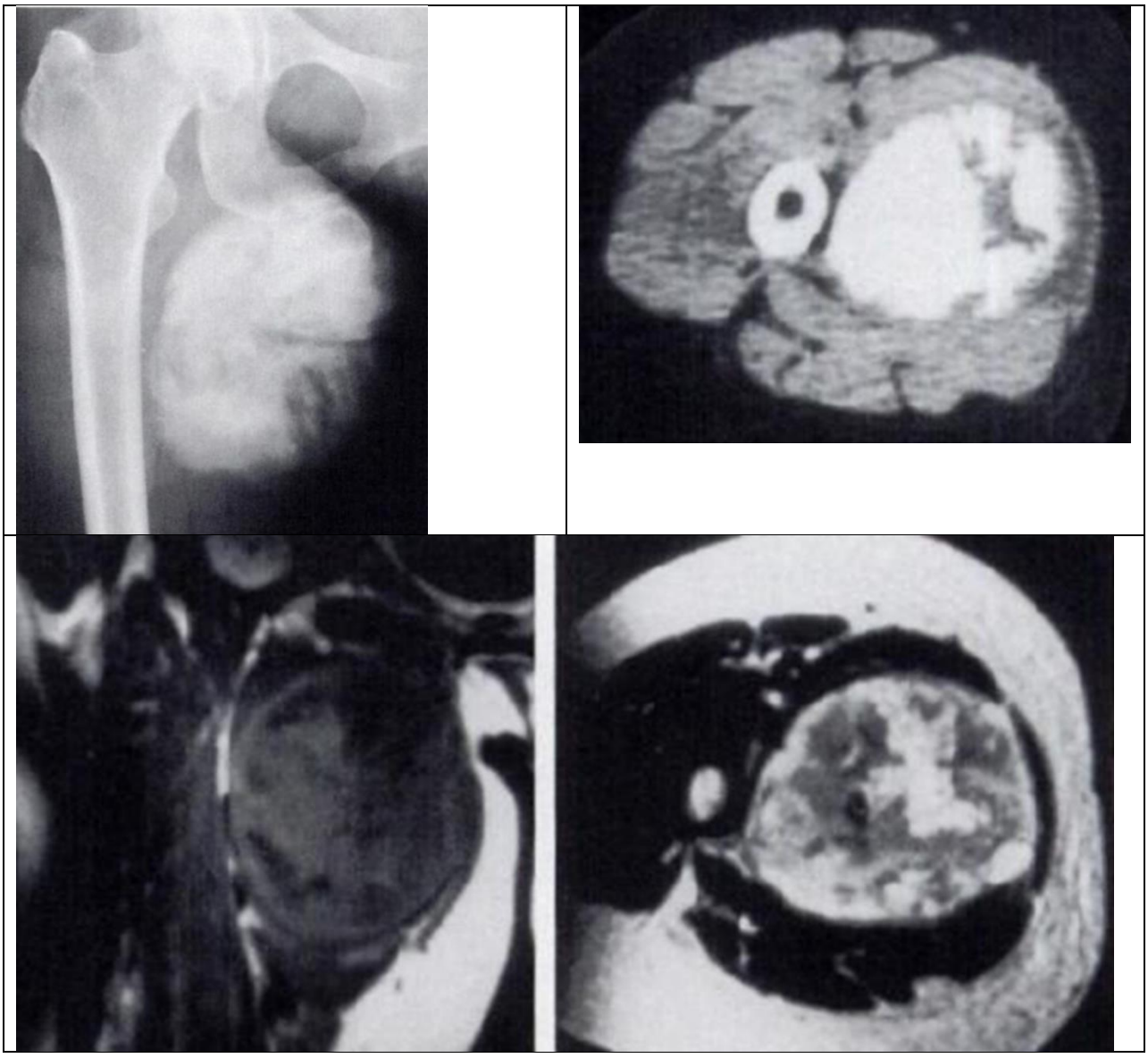
10) Extraskeletal Osteosarcoma

- Rare – same histology
- Middle aged to older patients (mean 55 years)
- Extraskeletal osteosarcoma is a well-documented sequela of irradiation
- Malignant fibrous histiocytoma (MFH) is the most common postirradiation sarcoma.

Radiological Findings:

- Soft tissue mass with calcification or ossification
- Metastatic spread is common (~60% of all extraskeletal osteosarcomas) to the lungs (>80%), lymph nodes, and bone.





Ewing Sarcoma

- **<u>The Ewing sarcoma family</u>** of tumors includes:
  - ✓ **Osseous Ewing sarcoma**
  - ✓ **Extraskeletal Ewing sarcoma**
  - ✓ **Primitive neuroectodermal tumor**
  - ✓ **Askin tumor (Extraskletal ES of chest wall).**

- They share a karyotype abnormality with translocation involving chromosomes 11 and 22.
- Histologically, these lesions demonstrate crowded sheets of small round blue cells

A- Osseous Ewing Sarcoma

- 2nd most common primary malignant tumor of bone in children and adolescents (after OS)
- Overall, it is the 4th most frequent primary malignant tumor of bone after multiple myeloma, osteosarcoma, and chondrosarcoma

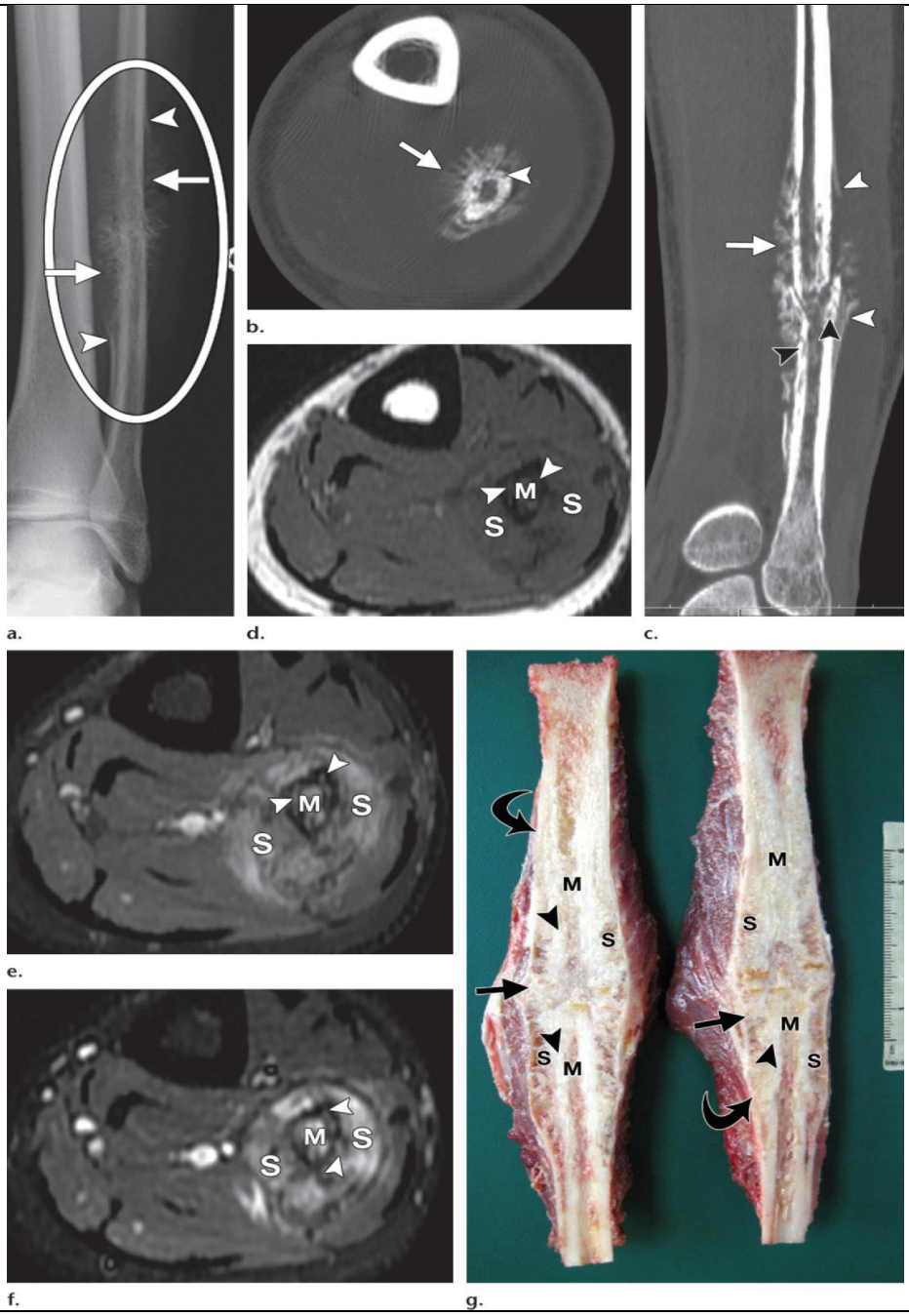
- Age: first 3 decades of life

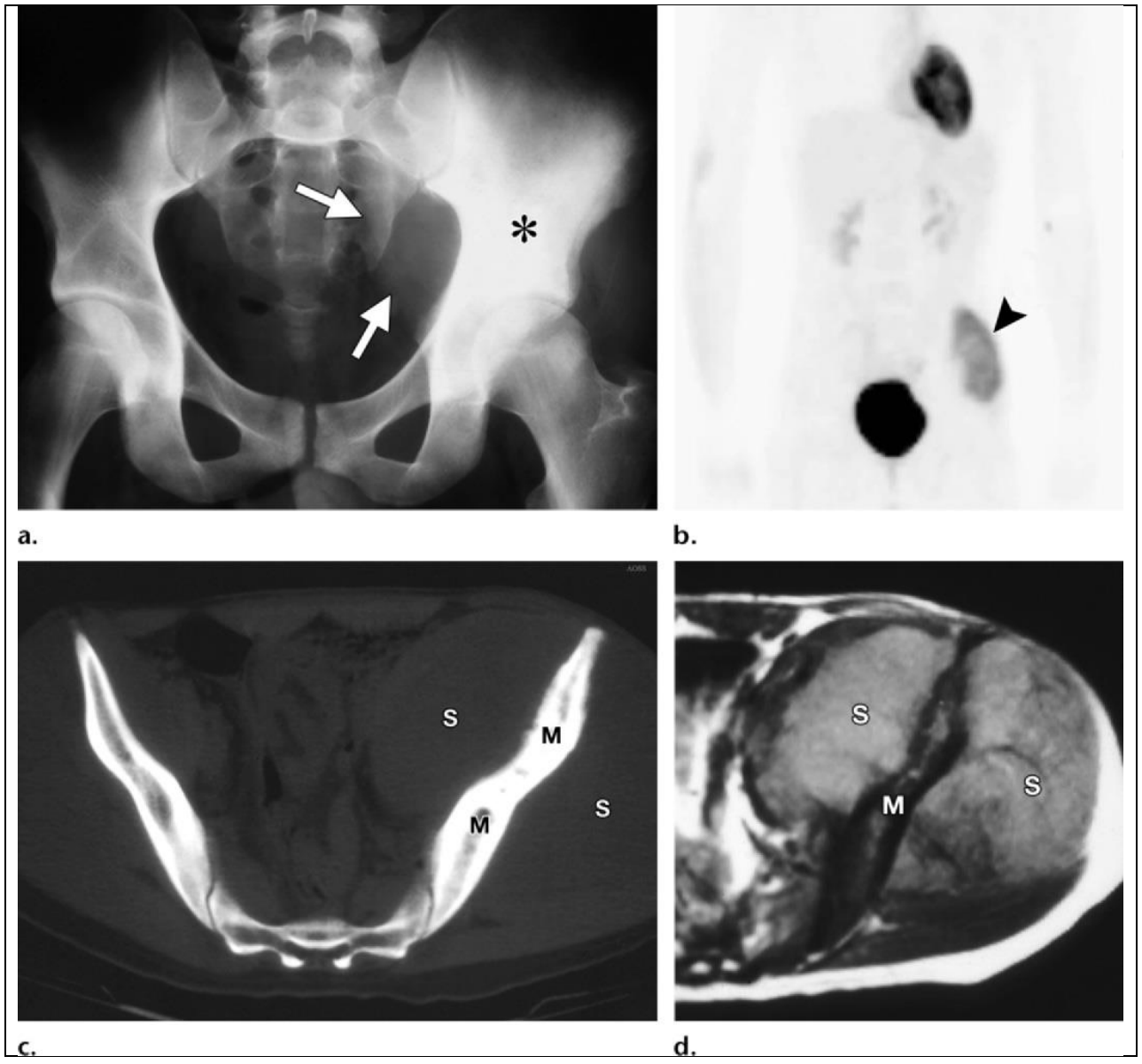
<u>Location & Distribution:</u>

- **<u>Long bones (70%):</u>**
  - Proximal > Distal
  - Metadiaphyseal (44%–59%)
  - Diaphyseal (33%–35%)
  - Metaphysis (5%–15%)
  - Femur (21%), Tibia (8%–11%), Humerus (10%), Fibula (7%–9%),
- **<u>Flat bones 25%</u>**
  - Pelvis:
    - Ilium (12%– 13%)
    - Sacrum (6%)
  - Ribs (8%), Scapula (4%–5%), hand or foot (3%–6%), mandible or maxilla (1%–2%), clavicle (2%), calvaria (1%), facial bones (0.5%), and sternum (0.2%)
- **<u>Vertebrae 5%</u>**

Radiological findings:

- Destruction lesion with a moth-eaten to permeative pattern
- Wide zone of transition (poor margination)
- Cortical destruction
- Periosteal reaction: lamellated (onionskin) or spiculated (sunburst)
- Soft-tissue mass

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B- Extraskeletal Ewing Sarcoma

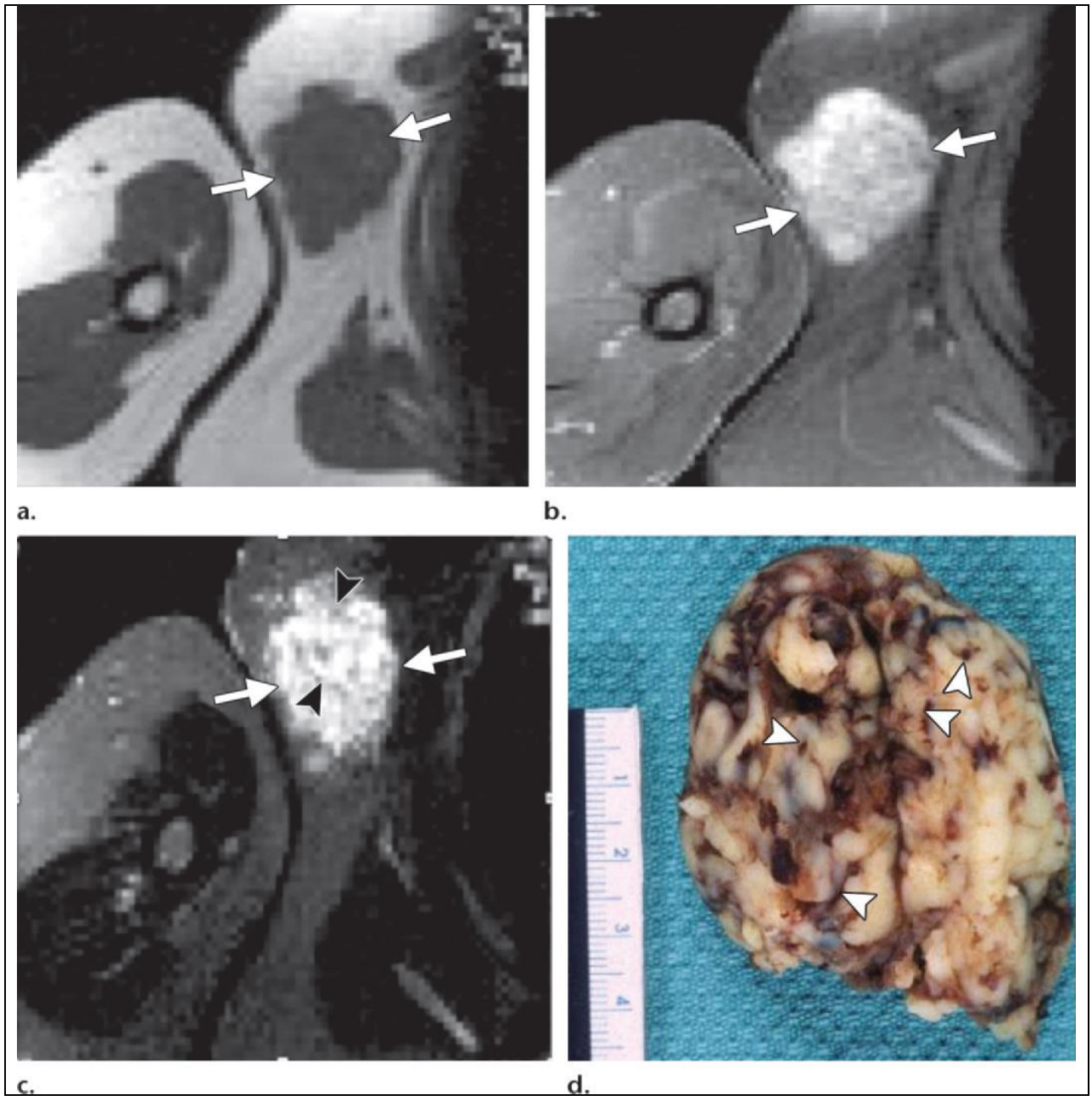
- Extraskeletal Ewing sarcoma is rare in comparison with Ewing sarcoma of bone
- Historically, Ewing sarcoma of soft tissue has included extraskeletal Ewing sarcoma and soft tissue PNET
- Age: young patients, (20 months - 30 years of age)

The following criteria are proposed for diagnosis of extraskeletal Ewing sarcoma:

- (a) No osseous involvement at MR imaging;
- (b) No increased uptake in bone or periosteum adjacent to the tumor on static images from bone scintigraphy
- (c) A lesion composed histologically of small round blue tumor cells with no differentiating features at light microscopy, immunohistochemical analysis, or electron microscopy
- (d) Demonstration of cytoplasmic glycogen

Radiological findings:

- ***Overall, imaging features of are nonspecific.***
- Large soft-tissue mass
- T1: Heterogeneous intermediate signal
- T2: Heterogeneous high signal
- Areas of hemorrhage appear as high signal intensity on all pulse sequences
- +C: Heterogeneous enhancement.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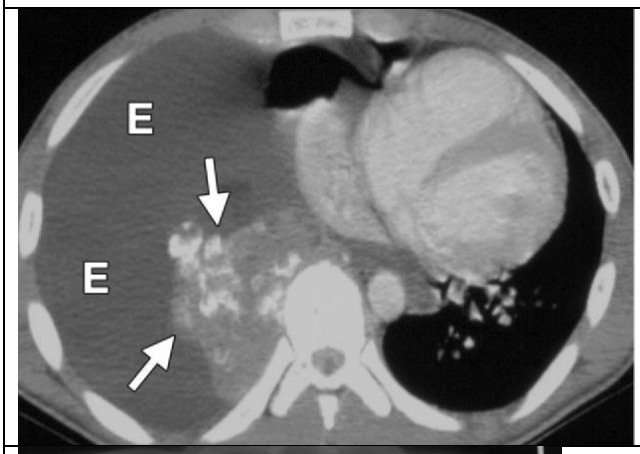
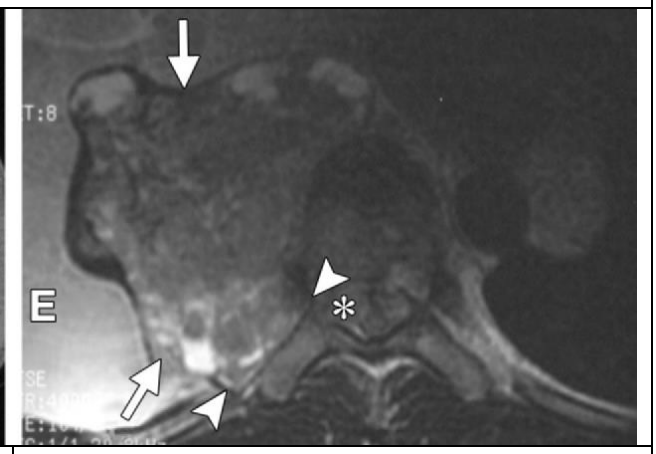
C- Askin Tumor

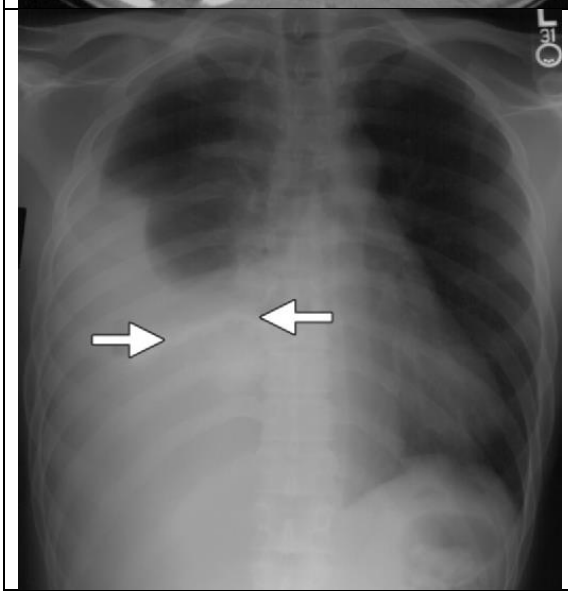
- Extraskeletal Ewing sarcoma or PNET located in the thoracopulmonary region is often referred to as Askin tumor
- Age: young adults and children

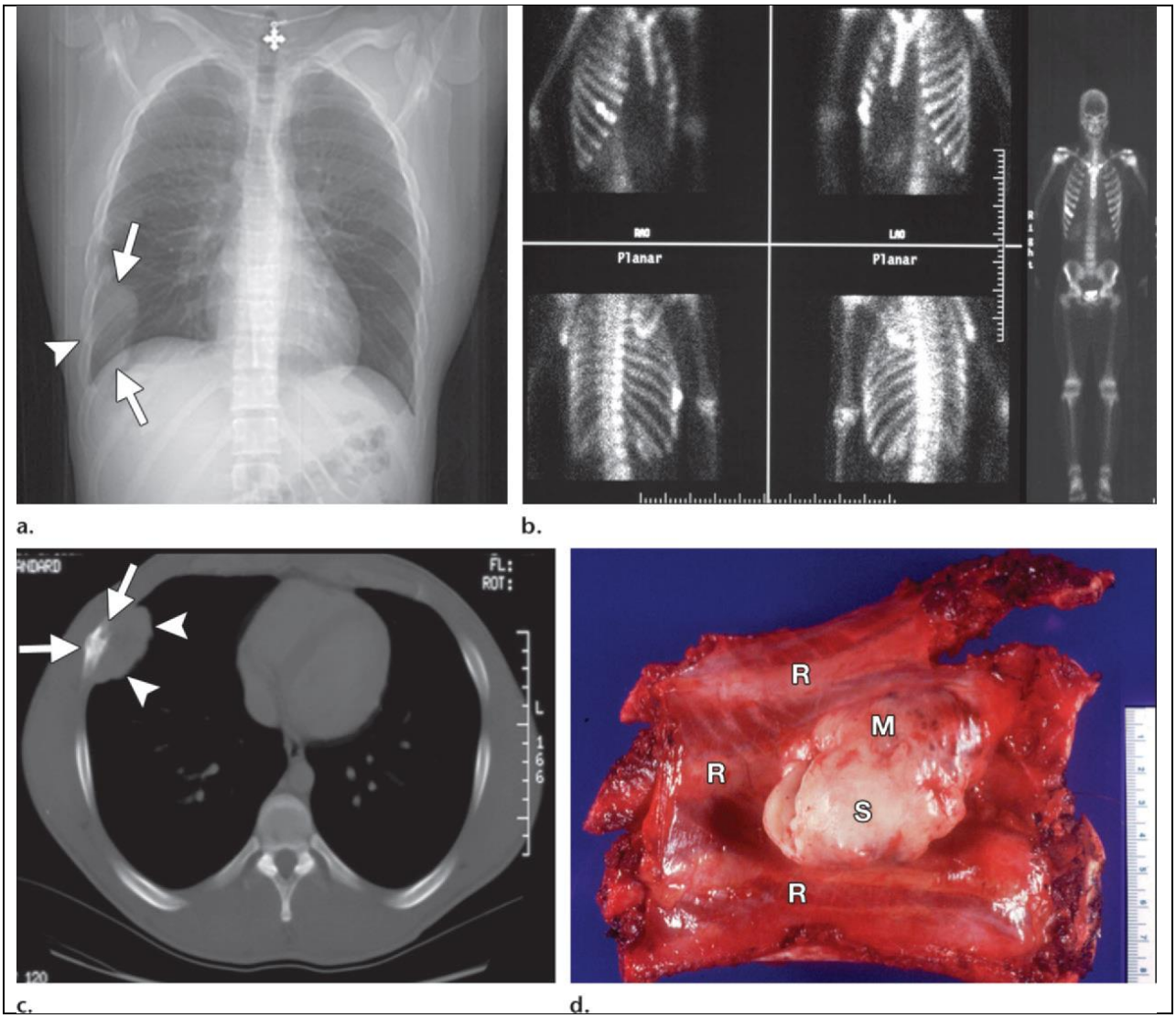
Imaging Findings:

- Unilateral Large chest mass is a common finding
- Represents a combination of a pleural-based mass and pleural fluid
- Pulmonary parenchymal disease may also be apparent in 25% of cases
- Rib destruction is frequently associated (63% of cases)
- Tumors often have both intrathoracic and extrathoracic components with pleural, pericardial, diaphragmatic, and vertebral or spinal extension and involvement





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Chondrosarcoma

Chondrosarcomas are malignant cartilaginous tumours that account for ~25% of all primary malignant bone tumours.

Age: 5th or 6th decades

Subtypes

i. Primary = De novo

- Conventional intramedullary chondrosarcoma (or central chondrosarcoma): low, intermediate or high grade
- Juxtacortical chondrosarcoma: low, intermediate or high grade
- Clear cell chondrosarcoma
- Myxoid chondrosarcoma: usually intermediate grade
- Mesenchymal chondrosarcoma: usually high grade
- Extraskeletal chondrosarcoma
- Dedifferentiated chondrosarcoma

ii. Secondary

Arising from pre-existing cartilaginous lesions:

- **Osteochondroma**
  - Solitary osteochondroma
  - Hereditary multiple exostoses
- **Enchondroma**
  - Solitary enchondroma
  - Ollier disease
  - Maffucci syndrome
- **Parosteal chondroma**

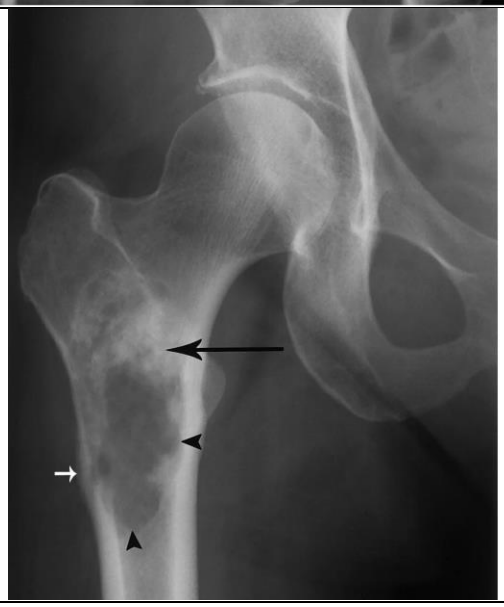
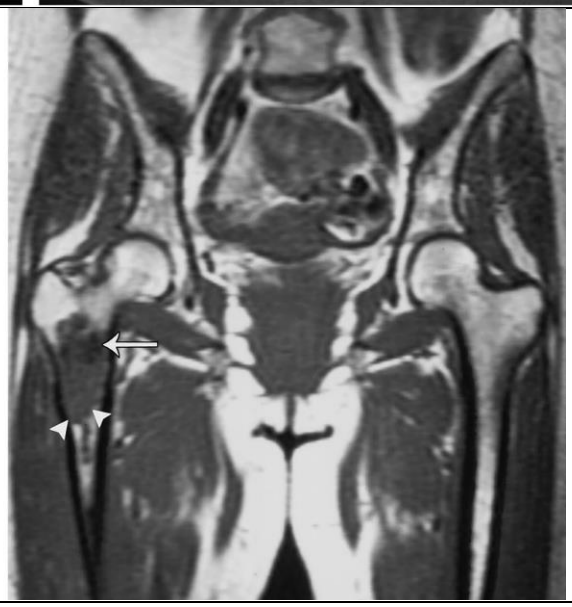
Distribution

- Long bones: 45%
  - Femur: 20-35%
  - Tibia: 5%
  - Upper limb (especially proximal humerus): 10-20%
- Pelvis: 25% especially around the triradiate cartilage
- Ribs: 8%

Radiological Findings:

- Lytic (50%)
- Intralesional calcifications: ~70% (rings and arcs calcification or popcorn calcification)
- Endosteal scalloping: affecting more than two-thirds of the cortical thickness (c.f. Less than two-thirds in enchondromas)
- Moth-eaten appearance or permeative appearance in higher grade tumours
- Cortical remodelling, thickening and periosteal reaction are also useful in distinguishing between an enchondroma and low-grade chondrosarcoma
- Cortical breach
- Soft tissue mass:

- T1: low to intermediate signal
- T2: very high intensity in non-mineralized/calcified portions
- GE/SWI: blooming of mineralized/calcified portions
- T1 C+: heterogeneous moderate to intense contrast enhancement.

Soft Tissue Tumors

WHO Classification

Soft Tissue Tumors 2013

- ADIPOCYTIC TUMOURS
- FIBROBLASTIC / MYOFIBROBLASTIC TUMOURS
- FIBROHISTIOCYTIC TUMOURS
- SMOOTH MUSCLE TUMOURS
- PERICYTIC (PERIVASCULAR) TUMOURS
- SKELETAL MUSCLE TUMOURS
- VASCULAR TUMOURS
- GASTROINTESTINAL STROMAL TUMOURS
- NERVE SHEATH TUMOURS
- CHONDRO-OSSEOUS TUMOURS
- TUMOURS OF UNCERTAIN DIFFERENTIATION
- UNDIFFERENTIATED/UNCLASSIFIED SARCOMAS

1) Adypocitic Tumors

Benign

- Lipoma
- Lipomatosis
- Lipomatosis of nerve
- Lipoblastoma/lipoblastomatosis
- Angiolipoma
- Myolipoma of soft tissue
- Chondroid lipoma
- Spindle cell Lipoma/
- Pleomorphic lipoma
- Hibernoma

Intermediate (locally aggresive)

- Atypical lipomatous tumor/
  well differentiated liposarcoma

Malignant

- Dedifferentiated liposarcoma
- Myxoid liposarcoma
- Pleomorphic liposarcoma
- Mixed-type liposarcoma

2) Fibroblastic/Myofibroblastic Tumors

Benign

- Nodular fasciitis
- Proliferative fasciitis and proliferative myositis
- Myositis ossificans
- Elastofibroma
- Myofibroma/myofibromatosis
- Fibromatosis colli
- Fibroma of tendon sheath
- Desmoplastic fibroblastoma
- Calcifying fibrous tumor
- Angiofibroma
- Angiomyofibroblastoma
- Gardner fibroma
- Giant cell angiofibroma

Intermediate (locally aggresive)

- Superficial fibromatosis
  - (plantar/palmar)
- Desmoid-type fibromatosis
- Lipofibromatosis

Intermediate (rarely metastasizing)

- **Solitary fibrous tumor- SFT- (Hemangiopericytoma)- HPM**
- Myofibroblastic inflammatory tumor
- Myofibroblastic sarcoma
- Dermatofibrosarcoma protuberans - **DP-**

Malignant

- Adult Fibrosarcoma
- Myxofibrosarcoma (previously myxoid malignant fibrous histiocytoma)

3) Fibrohistiocytic Tumors

So-called fibrohistiocytic	
Benign	GCT of tendon sheath, diffuse-type giant cell, deep benign fibrous histiocytoma
Intermediate (rarely metastasizing)	GCT of soft tissues

4) Smooth Muscle Tumors

Benign

- Leiomyoma of soft tissue

Malignant

- Leiomyosarcoma

5) PERICYTIC (PERIVASCULAR) TUMORS

Glomus tumor, myopericytoma

- **Angioleiomyoma**

6) Skeletal Muscle Tumors

Skeletal muscle	
Benign	Rhabdomyoma
Malignant	Rhabdomyosarcoma: embryonal, alveolar, pleomorphic

7) VASCULAR TUMORS

Benign

- Haemangioma
- Epithelioid haemangioma
- Angiomatosis
- Lymphangioma

Intermediate (locally aggresive)

- Kaposiform haemangioendothelioma

Intermediate (rarely metastasizig)

- Papillary intralymphatic angioendothelioma
- Haemangioendothelioma
- Kaposi sarcoma

Malignant

- Haemangioendothelioma
- Angiosarcoma

8) Chondro-Osseous Tumors

Benign

- Soft tissue chondroma

Malignant

- Extraskeletal mesenchymal chondrosarcoma
- Extraskeletal osteosarcoma

9) Gastrointestinal Stromal Tumors

10) Nerve Sheath Tumors

Benign

- Schwannoma (Neurinoma)
- Neurofibroma (NF)

Malignant

- Malignant Peripheral nerve sheath tumor (MPNSTs)

11) Tumors Of Uncertain Differentiation

Benign
- Myxoma
- Angiomyxoma

Intermediate (rarely metastasizing)
- Ossifying fibromyxoid tumour
- Angiomatoid fibrous histiocytoma
- Mixed tumour/Myoepithelioma
- Phosphaturic mesenchymal tumor

Malignant
- Synovial sarcoma
- Epitheliod sarcoma
- Alveolar soft part sarcoma
- Extraskeletal myxoid chondrosarcoma
- Desmoplastic small round cell tumor
- Clear cell sarcoma of soft tissue
- Ewing's sarcoma of soft tissue
- PEComa

12) Undifferentiated/Unclassified Sarcomas

- Undifferentiated spindle cell sarcoma
- Undifferentiated pleomorphic sarcoma
- Undifferentiated round cell sarcoma
- Undifferentiated epitheliod sarcoma
- Undifferentiated sarcoma, not otherwise specified

MRI Imaging Algorithm ☺

❖Specific MRI Features
➢ Hyperintense T1
➢ Hyperintense T2
➢ Hypointense T2
➢ Calcification / Ossification
❖Non-Specific MRI Features
➢ Pediatric
➢ Adult
❖Specific Location

❖ Common Pediatric Soft Tissue Sarcoma
• Rhabdomyosarcoma (1st Common) • Non-Rhabdomyosarcoma: ○ Synovial sarcoma ○ Infantile Fibrosarcoma ○ Malignant Peripheral Nerve Sheath Tumor ○ Ewing Sarcoma Family
❖ Common Adult soft Tissue sarcoma
• Undifferentiated Pleomorphic sarcoma (1st common) • Liposarcoma (2nd Common)

❖ Role Of Imaging ☺

Local Staging of soft-tissue sarcomas => MRI:

- **Location of the lesion**
- **Size of the lesion**
- **Compartmental extent of the mass**
- **Neurovascular involvement**
- **Extension to the underlying bone**
- **Extension to the adjacent joint**

Distant Staging :

- **CT chest**
- **CT abdomen and pelvis**
- **MRI spine**
- **Bone scan or PETCT**

❖ Neurovascular Bundle Status

- Intact neurovascular bundle = is determined by the presence of a fat plane of separation between the neurovascular bundle and the tumor.
- Involved neurovascular bundle = the fat plane is obliterated

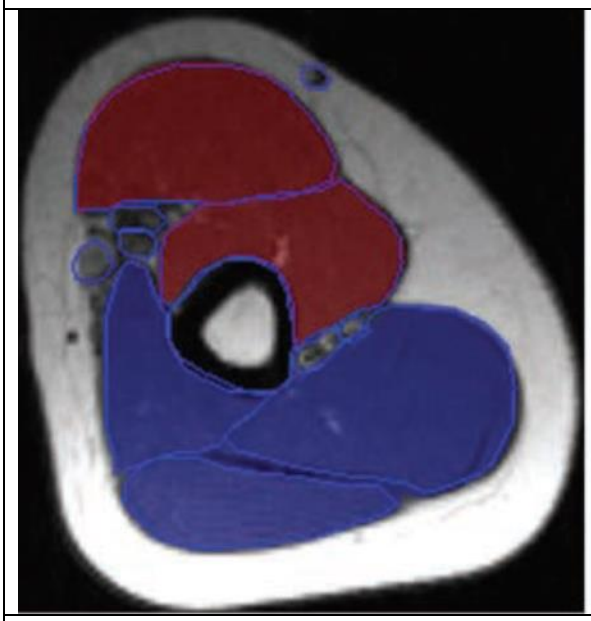
❖Anatomic Compartmentalization of the Mass

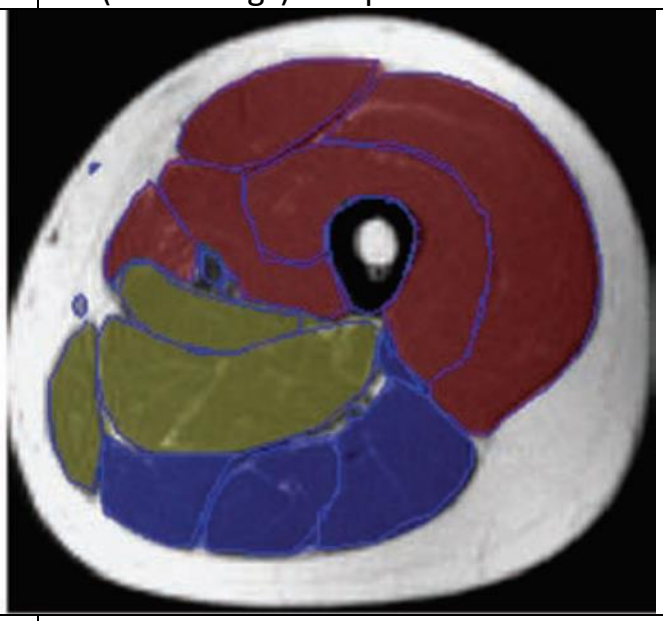
Arm:

- Anterior and posterior compartments.

Thigh:

- Anterior (quadriceps), medial (abductors), and posterior (hamstrings) compartments.



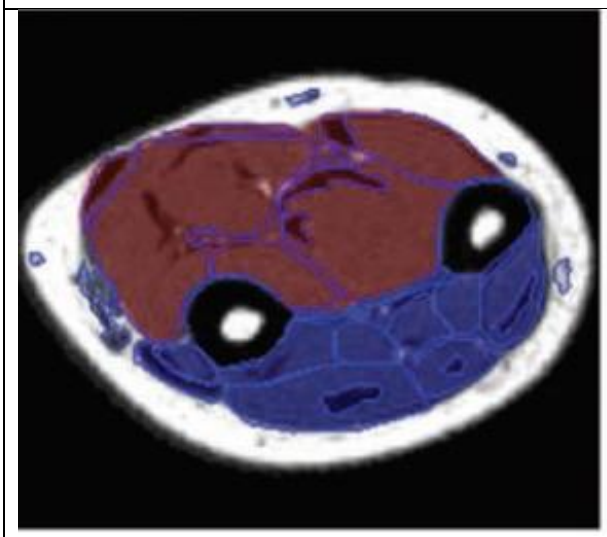


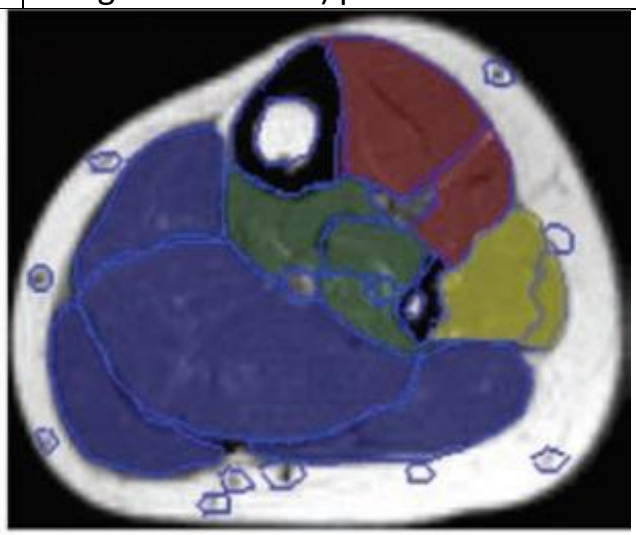
Forearm:

- Volar (flexor) and dorsal (extensor) compartments.

Calf:

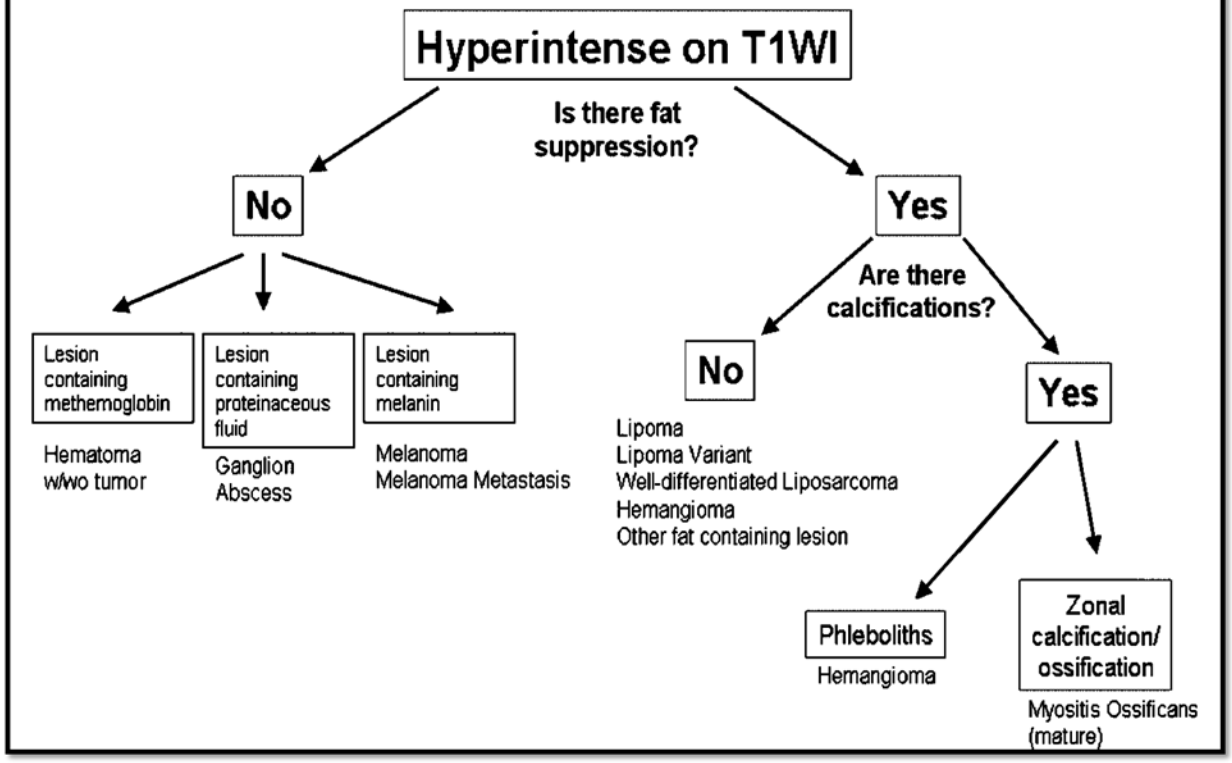
- Anterior, lateral, and deep and superficial (soleus and gastrocnemius) posterior.



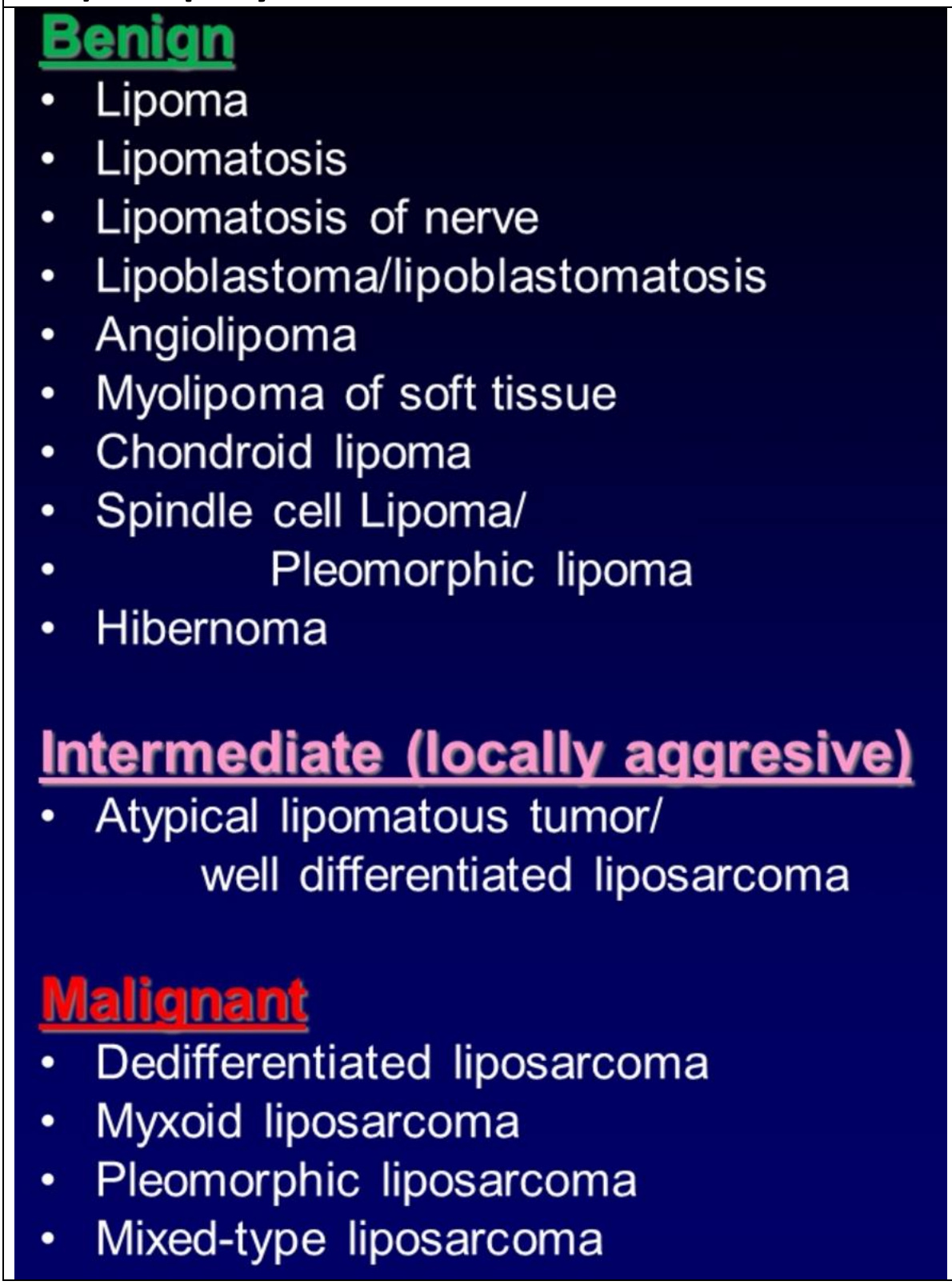


I- Hyperintense T1 Lesions

T1 hyperintense	
Lesion containing fat	Lipoma, lipoma variant, well-differentiated liposarcoma, hemangioma, myositis ossificans (mature)
Lesion containing methemoglobin	Hematoma
Lesion containing proteinaceous material	Ganglion, abscess
Lesion containing melanin	Melanoma



A) Adipocytic Tumors



1) Lipoma

- Benign tumours composed of mature adipocytes.
- Most common soft tissue tumour
- 50% of all soft tissue tumors
- 2% of the population
- Age: adulthood (5th-7th decades)

Location:

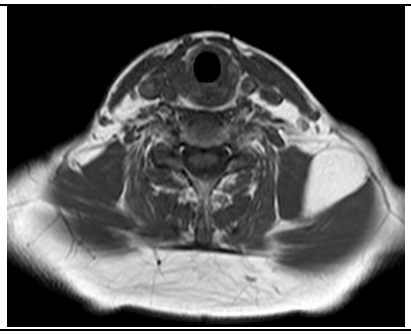
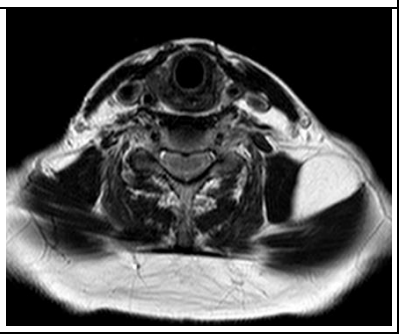
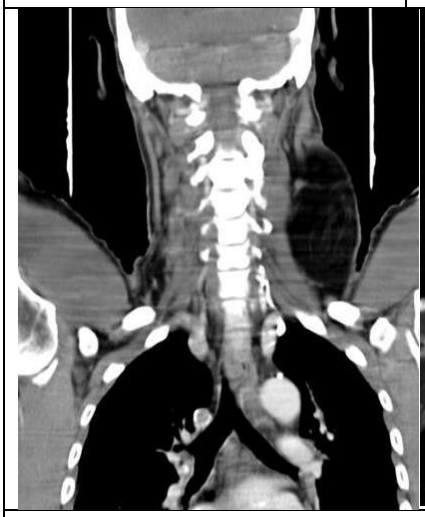
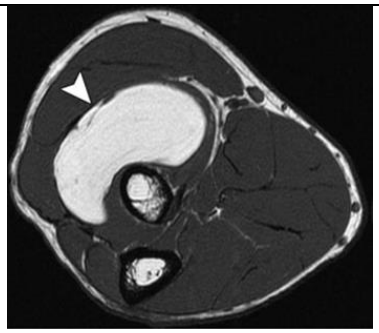
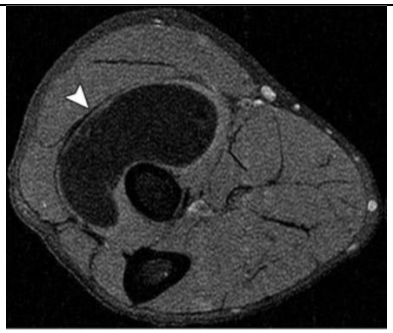
- central nervous system and spine
- Upper back
- Neck
- Proximal extremities
- Abdomen

Types:

- Superficial:
  - Subcutaneous
  - Subfascial
- Deep:
  - Intramuscular
  - Intermuscular

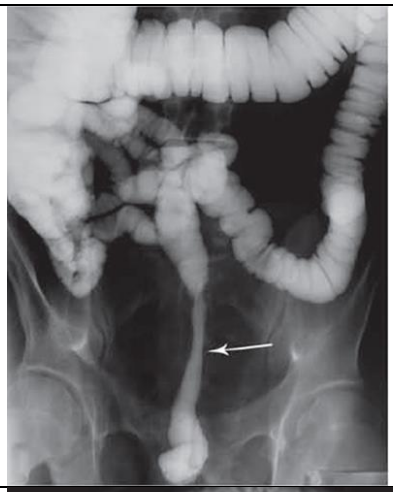
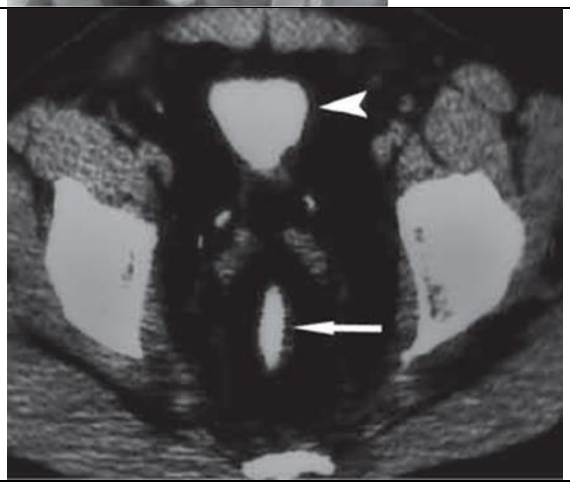
Imaging Findings:

- CT: -120 to -65 HU
- MRI: isointesne to fat in all pulse sequences.
- T1 & T2: homogeneously high signal intensity
- +C: NO enhancement.
- Low signal intensity on fat-suppressed images.
- A thin, fibrous capsule with low signal intensity may be seen around subcutaneous and intermuscular lipomas with all sequences.
- Intramuscular lipomas do not demonstrate a capsule but have irregular margins and tend to insinuate between the muscle fibers, creating a striated appearance

Axial CT	Axial T1	Axial T2
		
Coronal CT	Coronal T1	Coronal STIR
		
		

2) Lipomatosis

- Pelvic lipomatosis is the overgrowth of histologically benign, mature, white fat in the extraabdominal compartments of the pelvis along the perirectal and perivesicular spaces

Cystogram	Ba Enema
Urinary bladder displaced superiorly and anteriorly, as well as being compressed. The compression is usually symmetric, creating what has been described as either a pear shape or an inverted teardrop	The rectum appears both elongated and straightened, with superior displacement of the distal sigmoid colon On lateral views, the presacral space is thickened.
	
CT/MRI: • The pelvis appears crowded because of overabundant amounts of symmetrically distributed fat • Occasionally, the homogeneously deposited fat is disrupted by a few strands of fibrous tissue, but no soft-tissue mass is present. • The fat does not enhance and the soft-tissue planes of the pelvis are preserved.	

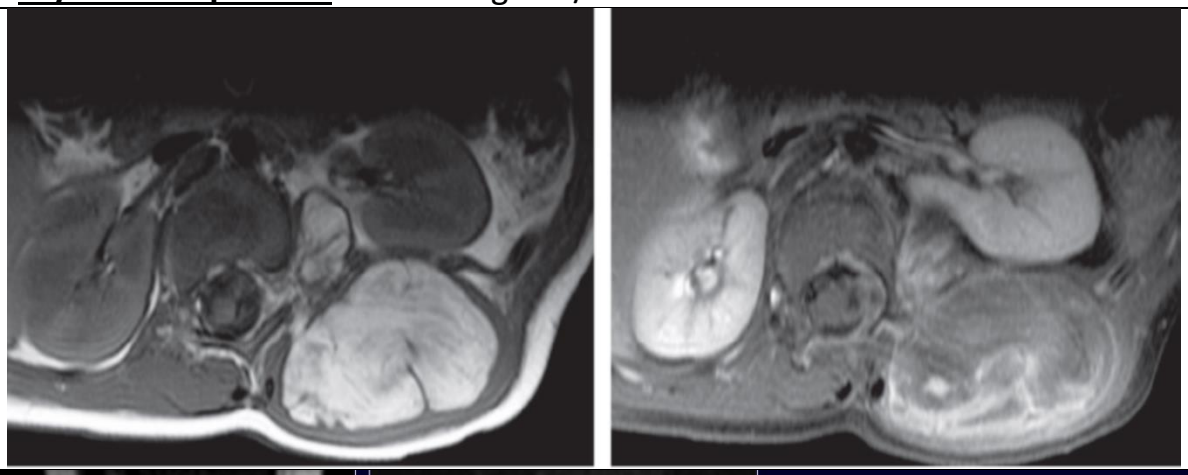
3) Lipoblastoma / Lipoblastomatosis

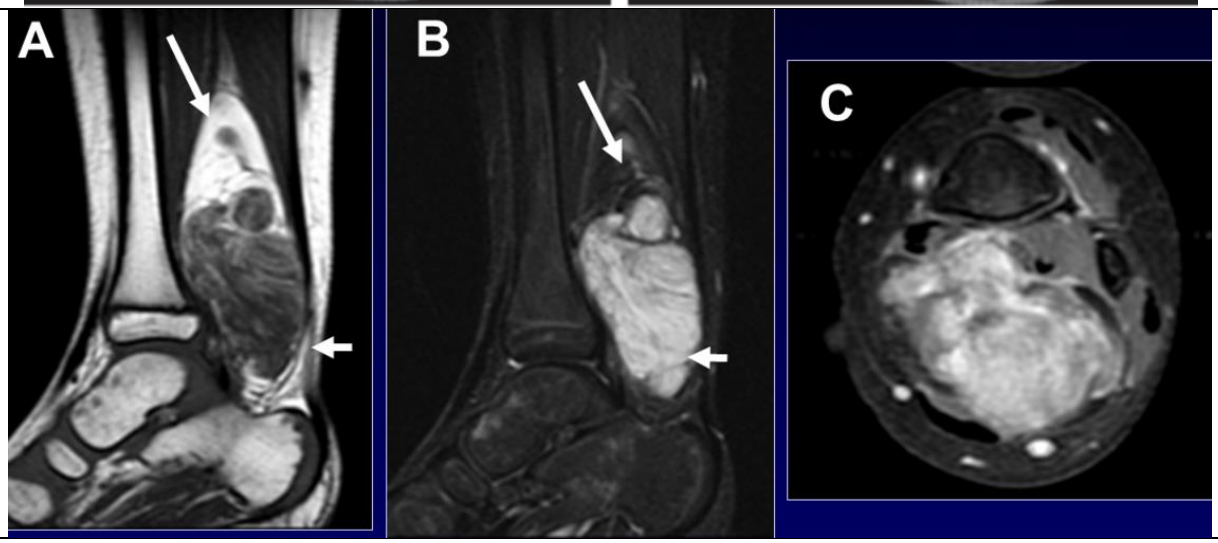
- Lipoblastoma and lipoblastomatosis are rare soft tissue neoplasms
- are derived from fetal adipose tissue
- Age: Infancy – early childhood.

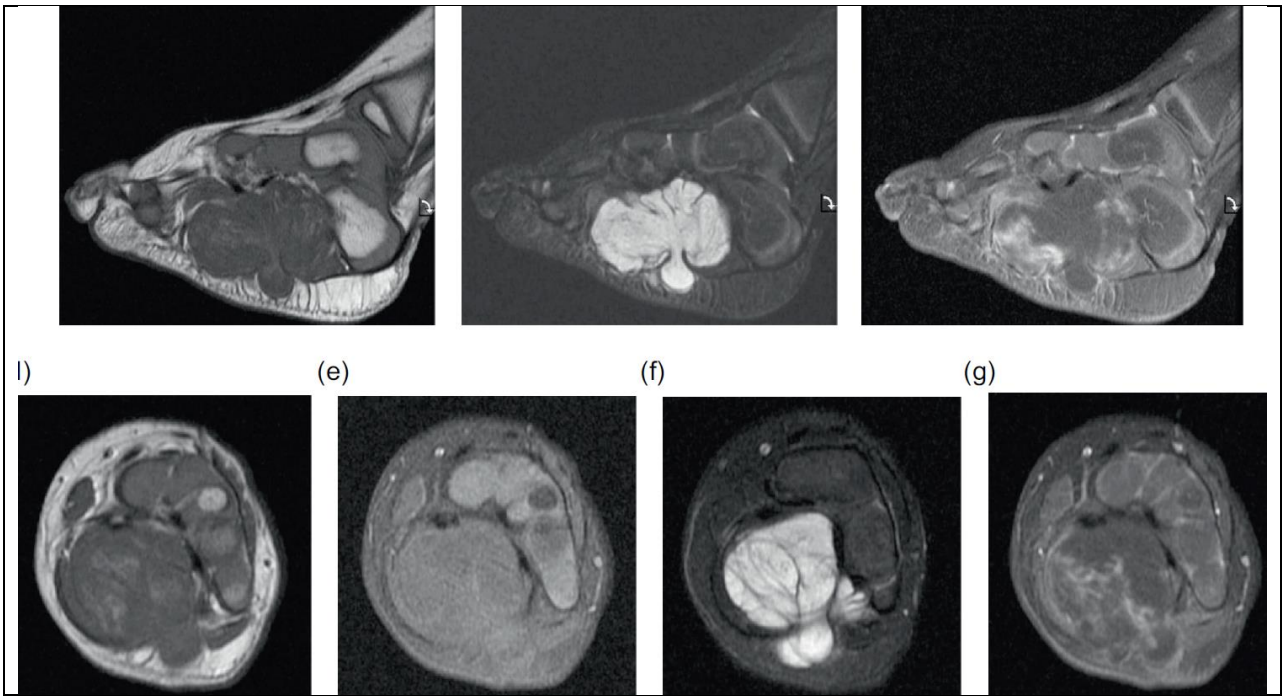
- Lipoblastomas tend to be encapsulated predominanatly fat containing lesion with internal septa
- Lipoblastomatosis is unencapsulated and shows signs of muscle infiltration.

Imaging Findings:

- **Adipose tissue**: High T1&T1 – Low signal on STIR – No enhancement
- **Myxoid component:** Low T1-High T2/STIR- diffuse enhancement.






l)
(e)
(f)
(g)

4) Hibernoma

- Hibernoma is a rare, benign, soft-tissue tumor composed of brown fat.

- Brown fat occurs in human newborns, but it substantially regresses by the age of 8 weeks.
- Residual brown fat may remain, however, and hibernomas may arise in these locations, which include:
    - Thigh, Buttock, Scapular region, Trunk, Neck, Mediastinum, Chest wall, Perirenal areas, Breast, Scalp, Periureteric regions

- A well-defined low-attenuation lesion with intratumoral septa is typically seen.

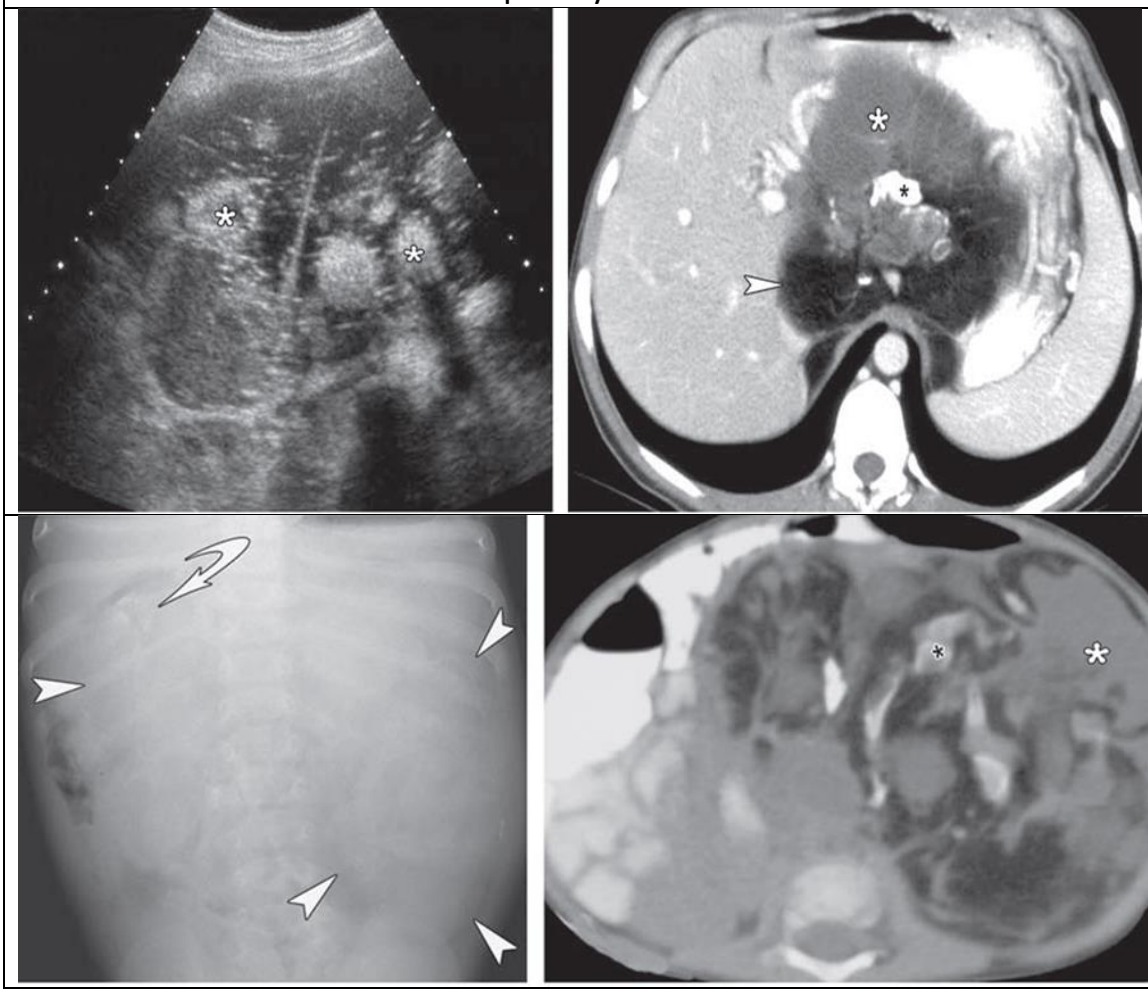
(d) (e) (f)

5) Teratoma

- Retroperitoneal teratomas represent approximately 1%–11% of all primary retroperitoneal Tumors.
- Teratomas usually occur in the ovaries, testes, anterior mediastinum, presacral and coccygeal areas, and retroperitoneum

Imaging findings:

- The morphologic features of teratoma extend from predominantly cystic to completely solid lesions.
- Fat and calcifications are frequently identified within these lesions.



6) Angiolipoma

- One of the many subtypes of a lipoma is an angiolipoma, which is a soft tissue tumor composed of mature fat and small blood vessels.
- Angiolipomas are also known as hemangiolipomas, vascular lipomas, or fibromyolipomas.
- Non-infiltrating and infiltrating subtypes

Imaging Findings:

- Mixture of soft tissue and fatty components on all imaging modalities.
- Make it difficult to differentiate this lesions from a liposarcoma

7) Liposarcoma

- Primary retroperitoneal sarcomas are both rare and diverse.
- Liposarcoma is the most common retroperitoneal sarcoma
- 35% of all malignant retroperitoneal soft-tissue tumors in adult patients.
- Age: 50–70-year age

Liposarcoma can be subclassified into 5 groups:

a) **Well-differentiated liposarcoma**
b) **Myxoid liposarcoma**
c) **Dedifferentiated liposarcoma**
d) **Pleomorphic liposarcoma**

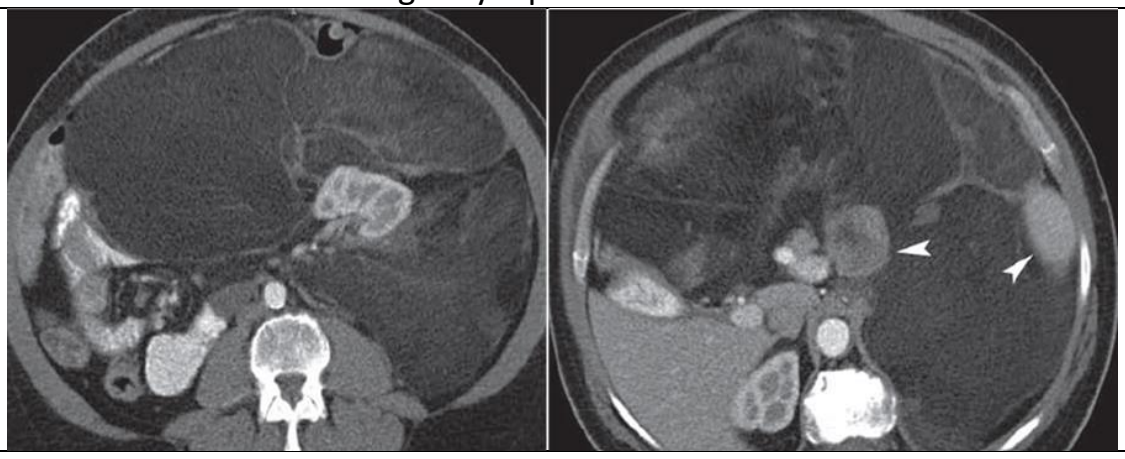
a) Well-differentiated Liposarcoma

- 1st common subtype of liposarcoma
- Low-grade tumors
- High rate of local recurrence
- Predominantly fat containing lesion +
- Enhancing solid areas / nodules / septae
- No clear demarcation between solid and fat

DD: large exophytic renal angiomyolipoma.

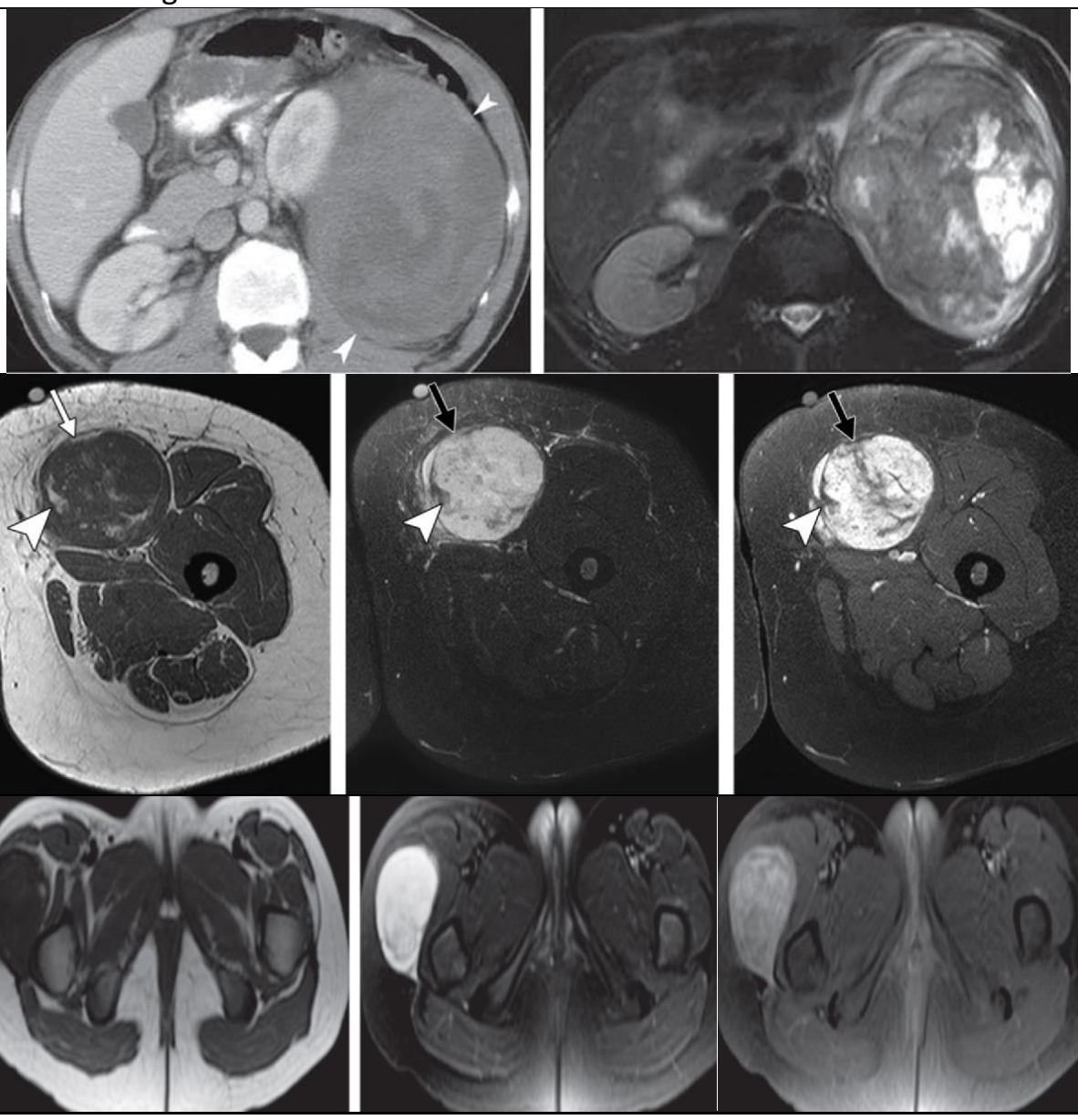
Features that suggest an angiomyolipoma are:

- Renal parenchymal defect from which the mass arises
- Enlarged intratumoral arteries.
- Presence of other angiomyolipomas



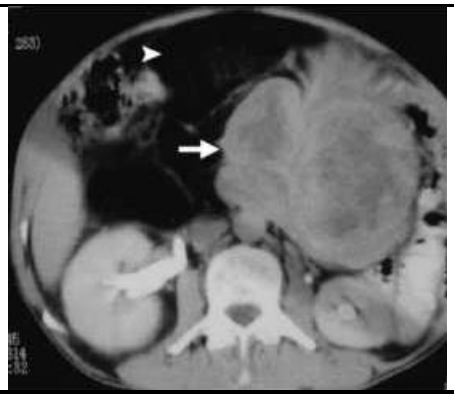
b) Myxoid Liposarcoma:

- 2nd most common subtype of liposarcoma
- Intermediate prognosis
- Myxoid matrix + small amounts of mature fat
- CT: Low attenuation
- **T1: Foci of high signal**
- **T2: High signal "pseudocystic"**
- +C: Heterogonous enhancement.



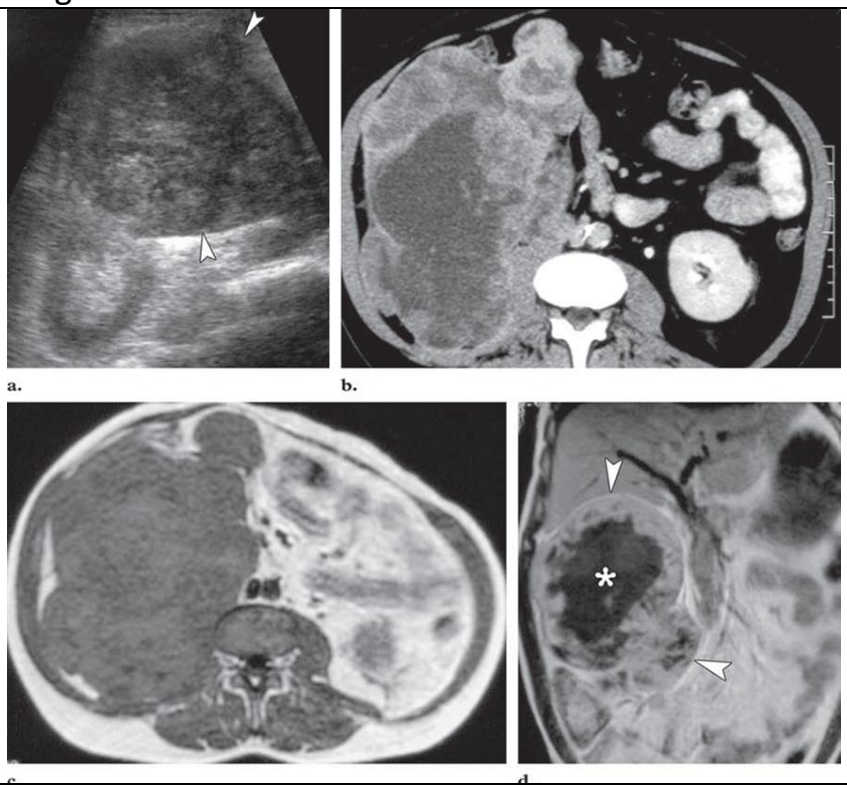
c) Dedifferentiated liposarcomas

- High-grade tumors with poor prognosis
- Areas of well differentiated liposarcoma and a non-lipogenic (dedifferentiated) component, which has an appearance of a high grade fibrosarcoma or MFH
- Areas with attenuation and SI characteristic of fat-containing well-differentiated liposarcoma
- Mass like areas of non-fatty tissue with higher attenuation as well as lower T1-W and higher T2-W SI



d) Pleomorphic and round cell Liposarcoma:

- Least common subtype of retroperitoneal liposarcoma.
- Nonspecific soft-tissue mass with little if any visible fat.
- Necrosis and hemorrhage may cause signal heterogeneity and nonenhancing areas.
- +C: heterogeneous enhancement



8) Parosteal Lipoma

- Parosteal lipomas are benign lesions composed of mature adipose tissue.
- Parosteal lipomas are not merely soft tissue lipomas located adjacent to periosteum, but rather demonstrate intimate association with the periosteum

- ***Osseous reaction is present in the underlying bone in up to 60% of cases:***
  - Hyperostotic and manifests as cortical thickening, sclerosis, calcification, or formation of an osseous excrescence.
  - If an osseous excrescence is formed (DD: Osteochondroma; the lesion can be differentiated given the lack of medullary continuity)
  - Less commonly the reactive bone change can manifest as smooth cortical scalloping or bowing

9) Intraosseous lipoma

Location: Calcaneal prevalence

Radiological Findings:

- Well defined lucent lesions
- Partial or complete marginal sclerosis
- Intralesional calcification

10) Neurovascular Lipomatous Lesions
Fibrolipomatous Hamartoma

- A fibrolipomatous hamartoma (FLH), also known as lipomatosis of nerve by WHO, refers to adipocyte proliferation within a peripheral nerve

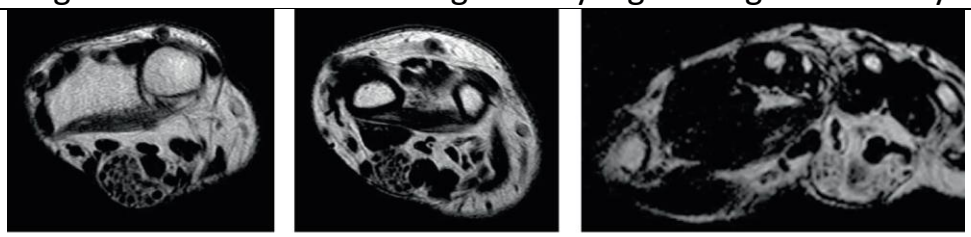
Location & Distribution:

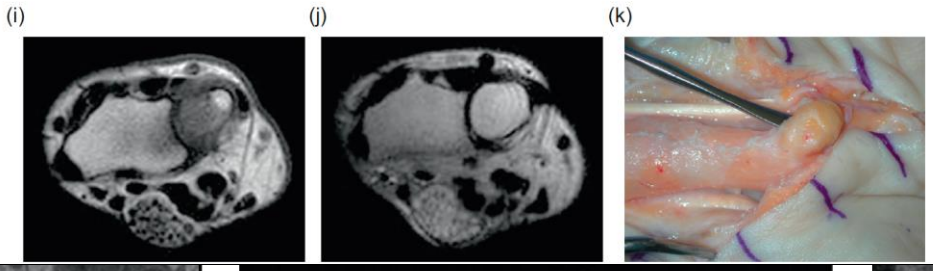
- Median nerve is involved in up to 50–85% of the cases
- Followed by radial or ulnar nerve involvement.
- The lower extremity nerves are rarely effected.

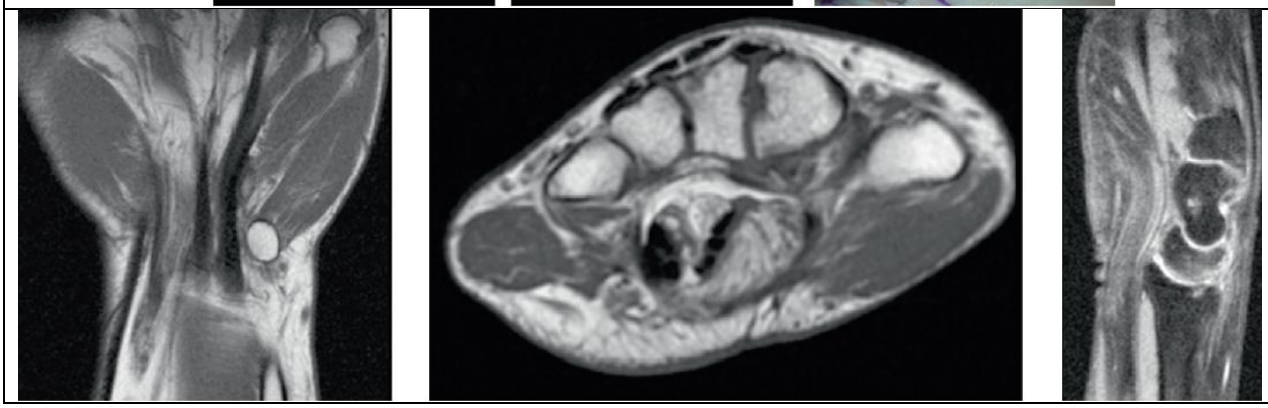
- Fibrolipomatous hamartomas have been associated with macrodystrophia lipomatosa in approximately 25% of patients.
- ***Macrodystrophia lipomatosa*** is a disorder of localized gigantism related to mesenchymal overgrowth within specific nerve distribution.

Imaging Findings:

- Low-T1 signal nerve fascicles are engulfed by high-T1 signal intensity fat







B) Metastatic Malignant Melanoma

- The least common skin cancer
- The most deadly skin cancer
- The most widely metastasising neoplastic disease
- Unpredictable pattern of spread.
- Predilection for young adults

Risk Factors:

- White race, Sun exposure, Age >14years
- Large number of nevi >50, Giant nevi
- Personal history of melanoma
- Family history of melanoma.

Early signs of melanoma include the ABCDEs:

- Asymmetry of lesion
- Border irregularity, bleeding, or crusting
- Color change or variegation (some lesions are amelanotic);
- Diameter larger than 6 mm or growing lesion;
- Evolving (surface changes: raised, bleeding, crusting or symptomatic itchiness or tenderness).

Imaging Modalities:

- PETCT, CT, MRI, Lymphoscintigraphy

Imaging Findings:

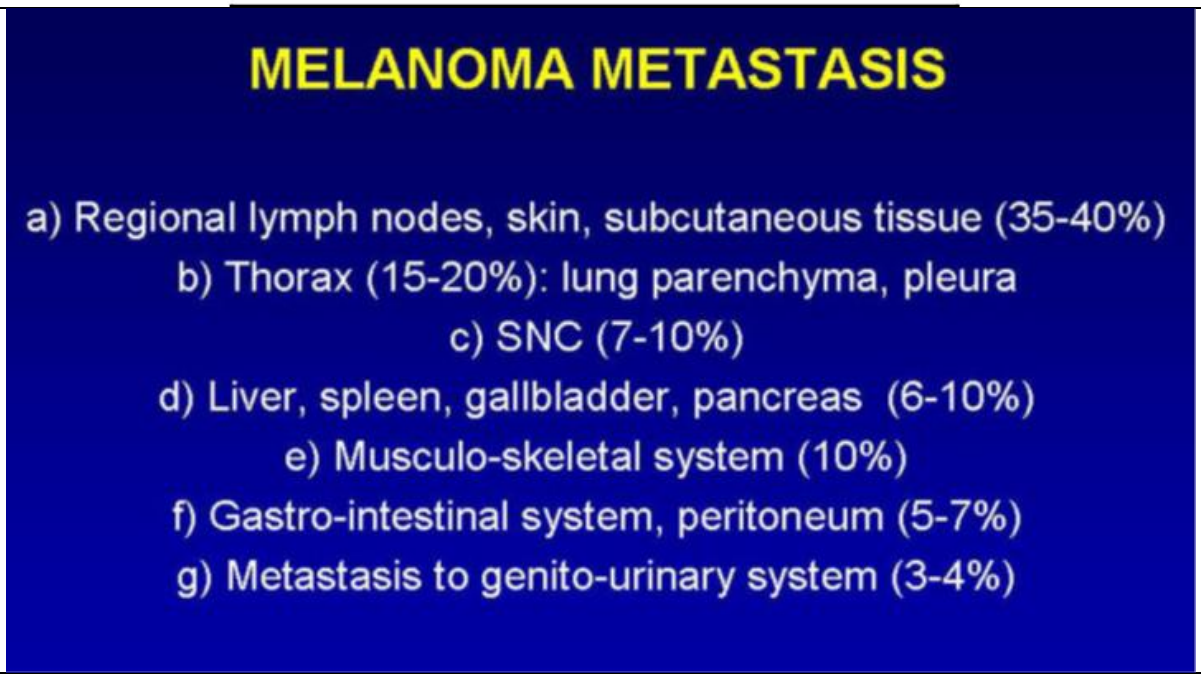
- T1: Intermediate to high signal
- T2: Mixed high and low signal
- +C: Heterogeneous enhancement

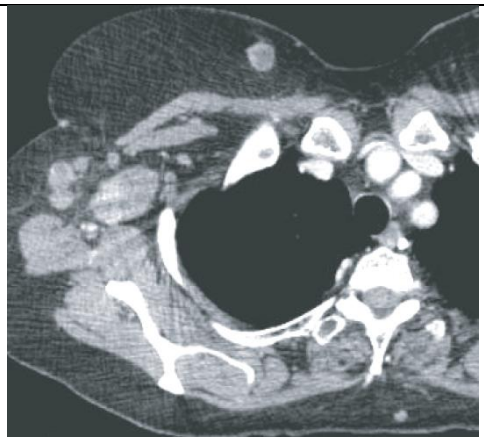
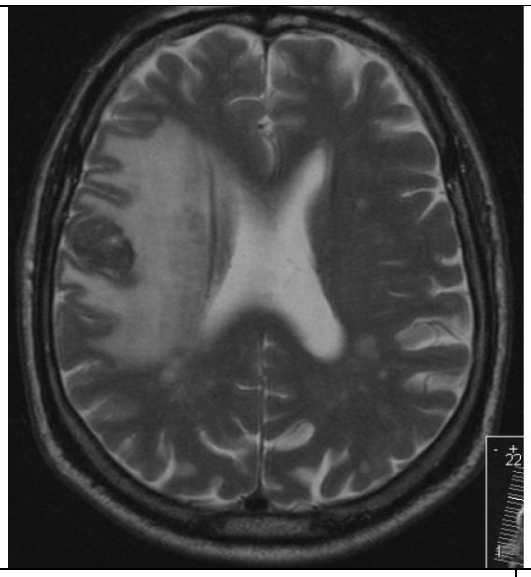
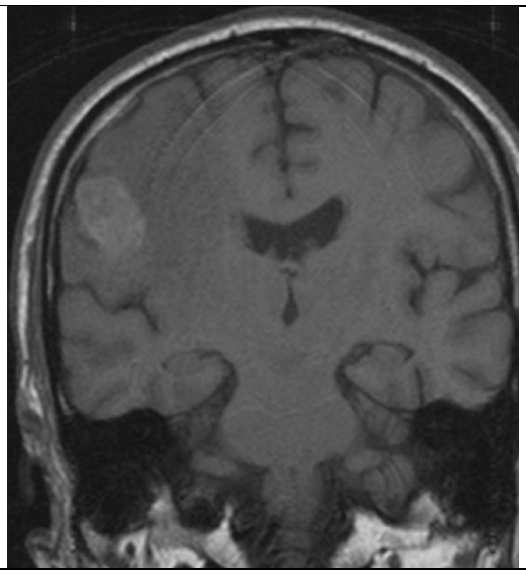
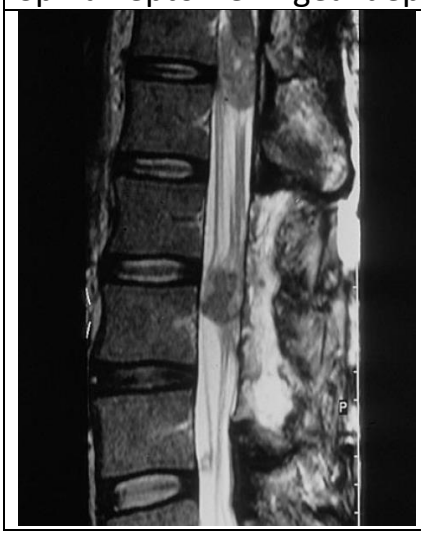
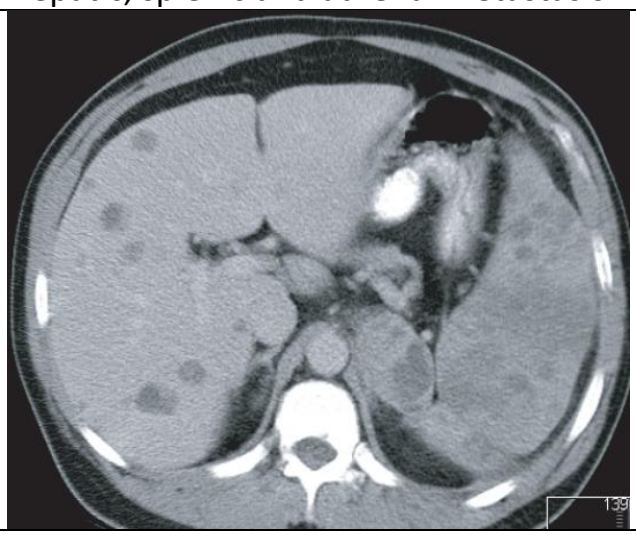
Clark Level	Histological tumour characteristics
Level 1	Confined to the epidermis; "*in situ*" melanoma
Level 2	Invasion of the papillary dermis
Level 3	Filling of the papillary dermis but not extending to the reticular dermis
Level 4	Invasion of the reticular dermis
Level 5	Invasion of the deep, subcutaneous tissue

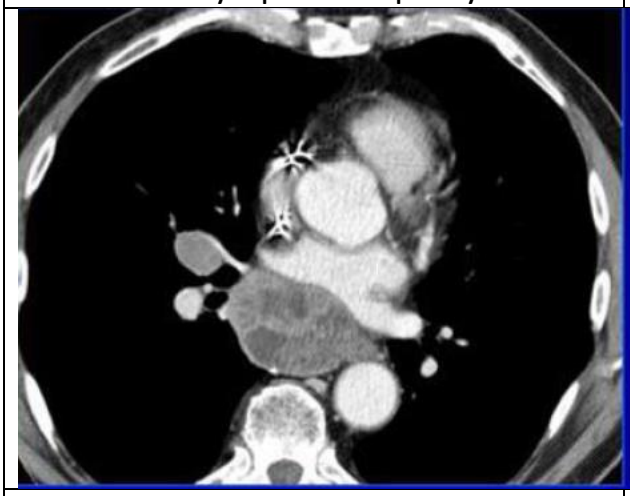
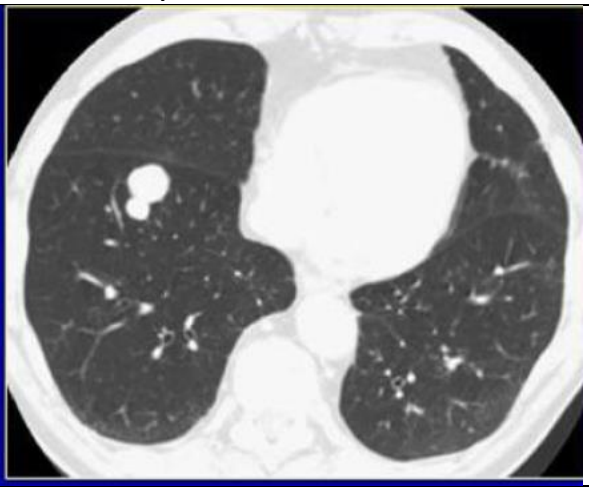
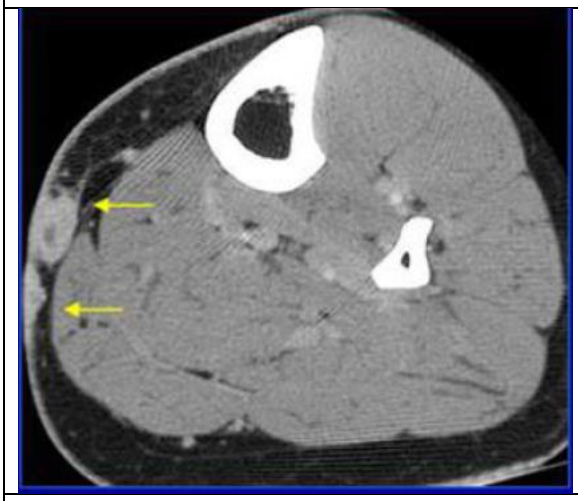
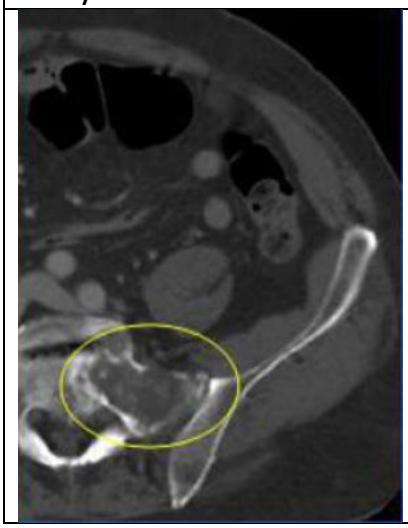
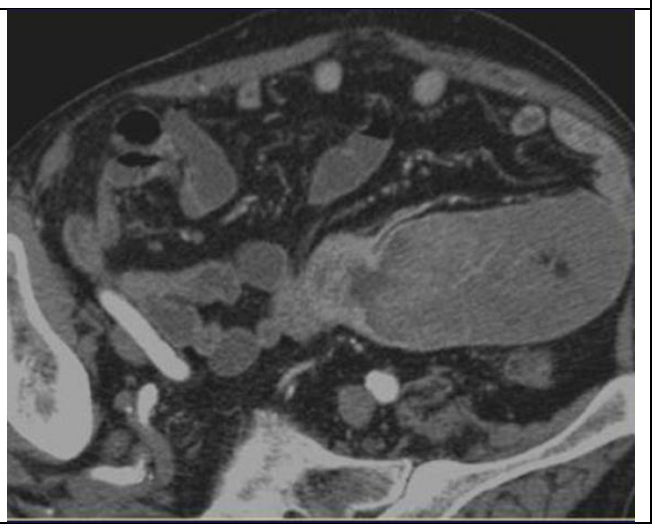
Breslow Thickness	5-year survival
< 1 mm	95-100%
1-2 mm	80-96%
2.1-4 mm	60-75 %
> 4 mm	37-50%

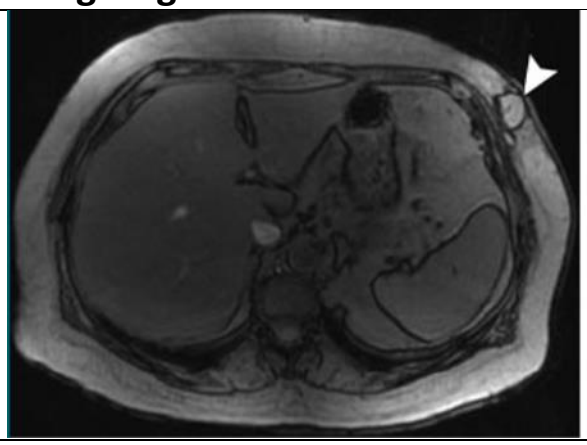
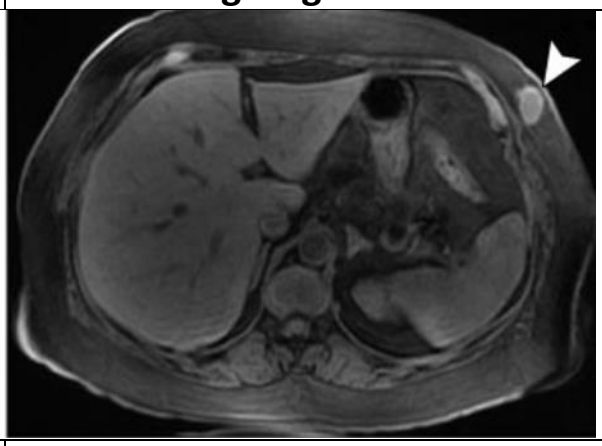
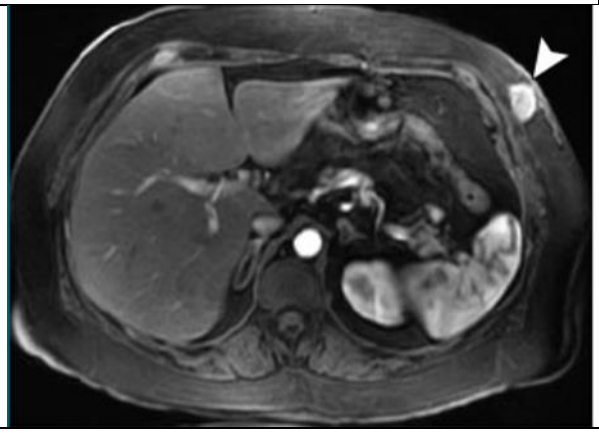
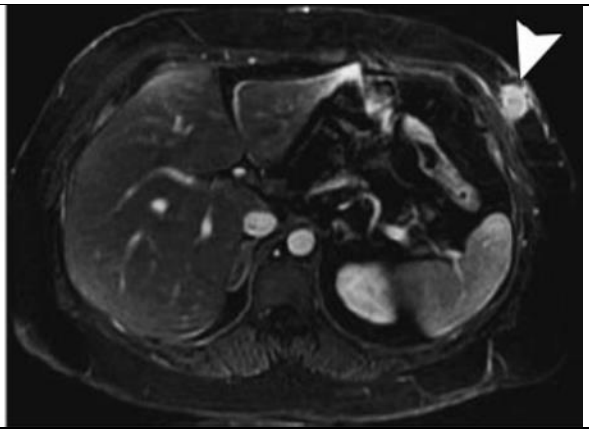
Table 1 AJCC revised version of the melanoma TNM classification[16]

T classification	Thickness	Ulceration status
T1	≤1.0 mm	a. without ulceration and level II/III b. with ulceration or level IV/V
T2	1.01–2.0 mm	a. without ulceration b. with ulceration
T3	2.01–4.0 mm	a. without ulceration b. with ulceration
T4	>4.0 mm	a. without ulceration b. with ulceration
N classification	No. of metastatic nodes	Nodal metastatic mass
N1	1 node	a. micrometastasis[a] b. macrometastasis[b]
N2	2–3 nodes	a. micrometastasis[a] b. macrometastasis[b] c. in transit met(s)/satellite(s) without metastatic nodes
N3	4 or more metastatic nodes, or matted nodes, or in transit met(s)/satellite(s) with metastatic node(s)	
M classification	Site	Serum lactate dehydrogenase
M1a	Distant skin, subcutaneous, or nodal metastases	Normal
M1b	Lung metastases	Normal
M1c	All visceral metastases Any distant metastases	Normal Elevated


MELANOMA METASTASIS
a) Regional lymph nodes, skin, subcutaneous tissue (35-40%)
b) Thorax (15-20%): lung parenchyma, pleura
c) SNC (7-10%)
d) Liver, spleen, gallbladder, pancreas (6-10%)
e) Musculo-skeletal system (10%)
f) Gastro-intestinal system, peritoneum (5-7%)
g) Metastasis to genito-urinary system (3-4%)

Inguinal LN metastasis	Breast metastasis
	
Cerebral Metastasis	
	
Spinal leptomeningeal deposits	Hepatic, splenic and adrenal metastasis
	

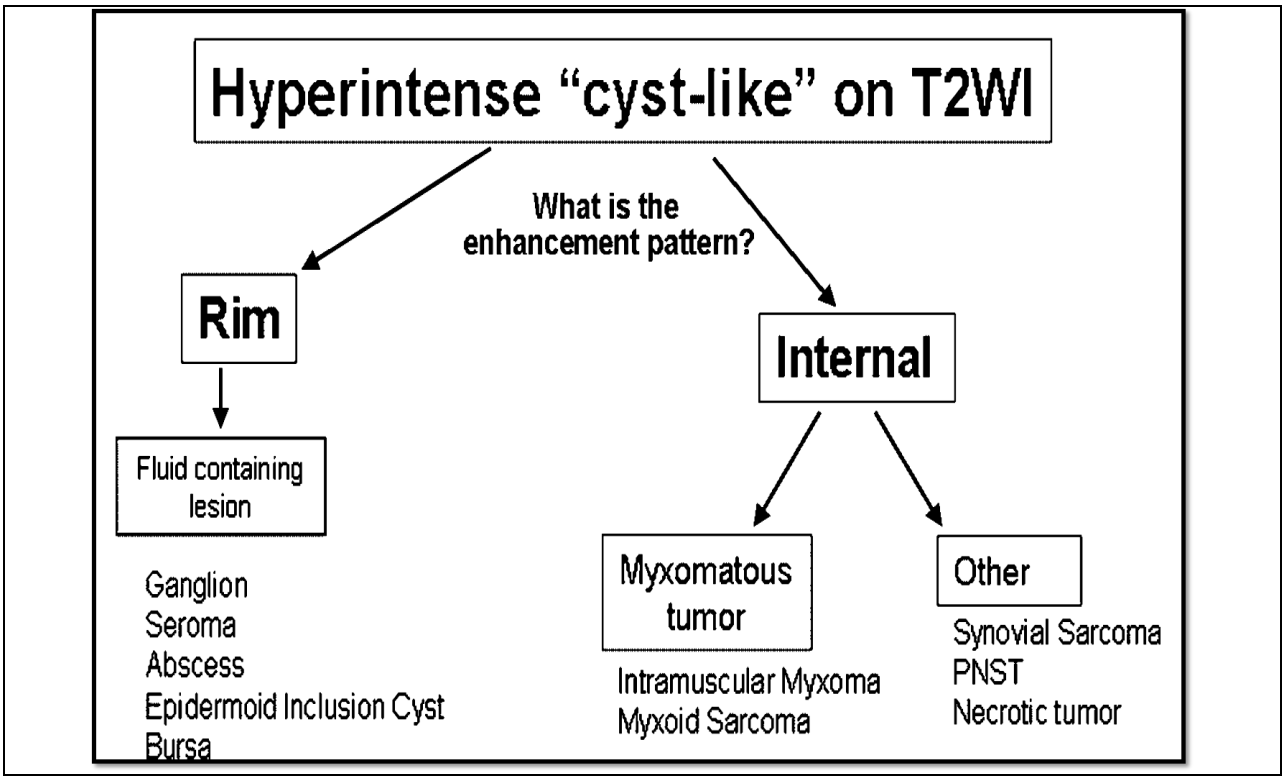
Mediastinal lymphadenopathy	Pulmonary nodules
	
Subcutaneous nodules	Intramuscular lesions
	
Bony letic lesions	GIT lesions
	

T1: High signal	SPGR FS: High signal
	
T1+C FS: Equivocal enhancement	**T1+C FS Subtraction: solid enhancement**
	

II- Hyperintense T2 Lesions

True Cyst	Pseudo-Cyst / Solid Tumor

• Ganglion cyst
• Synovial cyst
• Bursae
• Postsurgical collection (Seroma – lymphocele - Abscess)
• Hematoma
• Epidermoid Inclusion Cyst
• Hydatid cyst
 	
L☺☺K Intra-articular Cystic Lesions
	• **Benign Myxoid Lesions:**
	  ○ Myxoma
	  ○ Peripheral nerve sheath tumors
	• **Myxoid Sarcomas:**
	  ○ Myxoid liposarcoma
	  ○ Myxofibrosarcoma (Myxoid MFH)
	  ○ Myxoid leiomyosarcoma
	  ○ Extraskeletal myxoid chondrosarcoma
	• Synovial sarcoma
	• Vascular lesions
	• Glomus tumors



1) Intra-muscular Myxoma

- Rare benign type of soft tissue myxoma
- Mazabraud syndrome = intramuscular myxoma + fibrous dysplasia.
- Age: middle-aged women.

Location & Distribution:

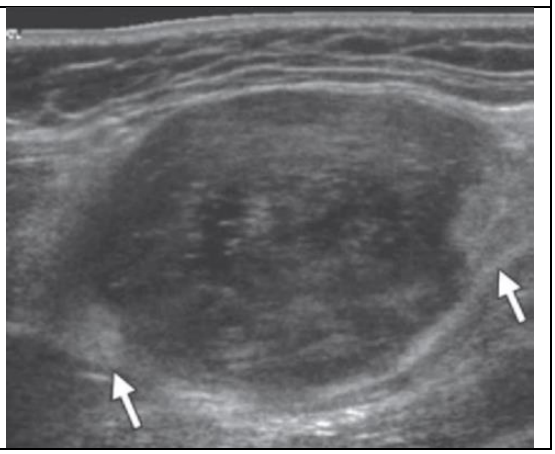
- Large muscles from the thighs, calf, buttocks, or shoulder girdle

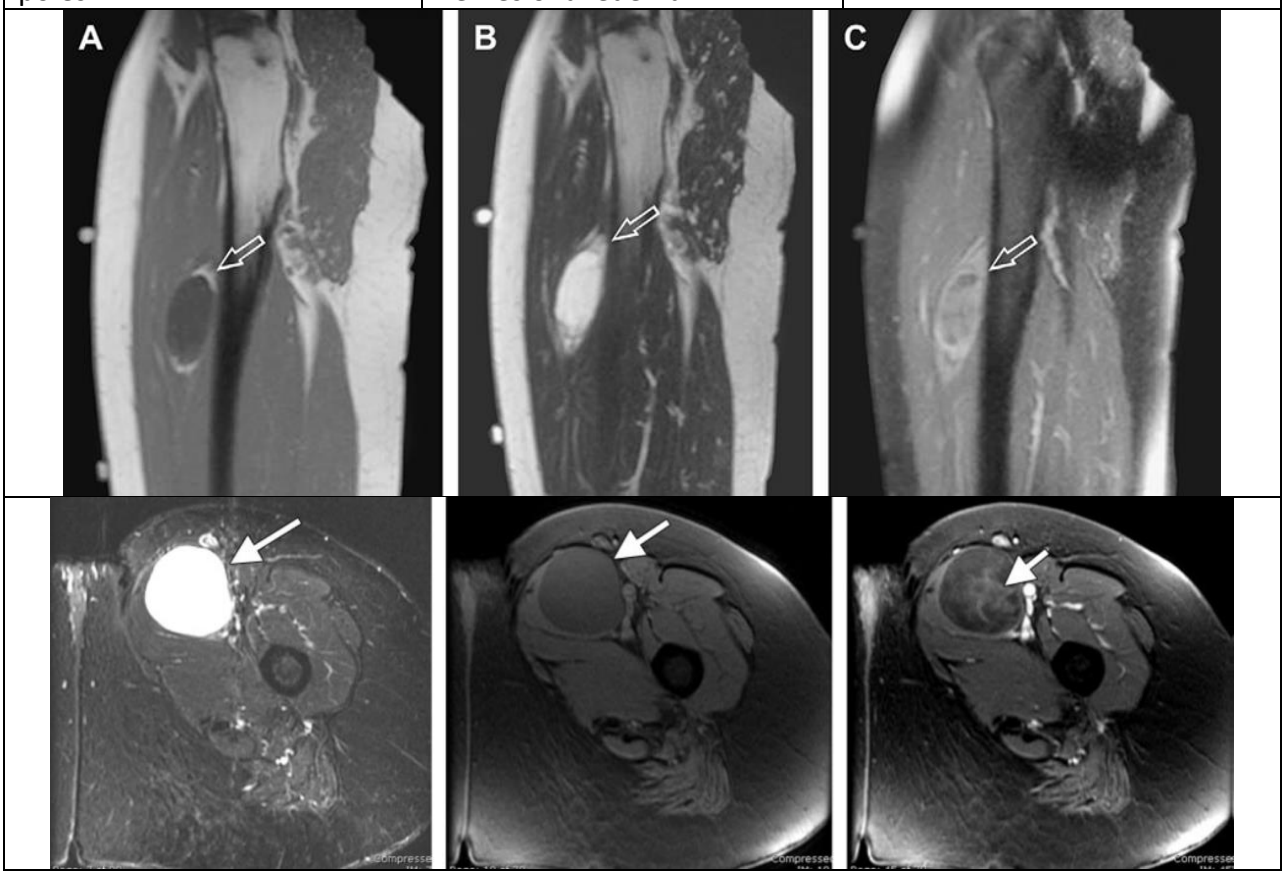
Imaging findings:

- A well-defined homogenous cystic-like lesion
- Surrounding rim of fat; most prominently at the superior and inferior poles of the lesion.
- Perilesional high T2/STIR signal intensity may be noted, a finding caused by leakage of the myxomatous tissue into the surrounding muscle
- T1: Low – Intermediate signal
- T2: High signal
- +C: mild – moderate homogenous contrast enhancement.

US

- Ovoid heterogeneous hypoechoic intramuscular mass.
- Increased echogenicity at the poles (arrows) represents fat.



T1: incomplete peripheral hyperintense fat rim at the poles	T2: Hyperintense lesion similar to signal of water Perilesional edema	T1+C FS: mild internal heterogeneous enhancement
		

2) Peripheral Nerve Sheath Tumors

a) Neurofibroma

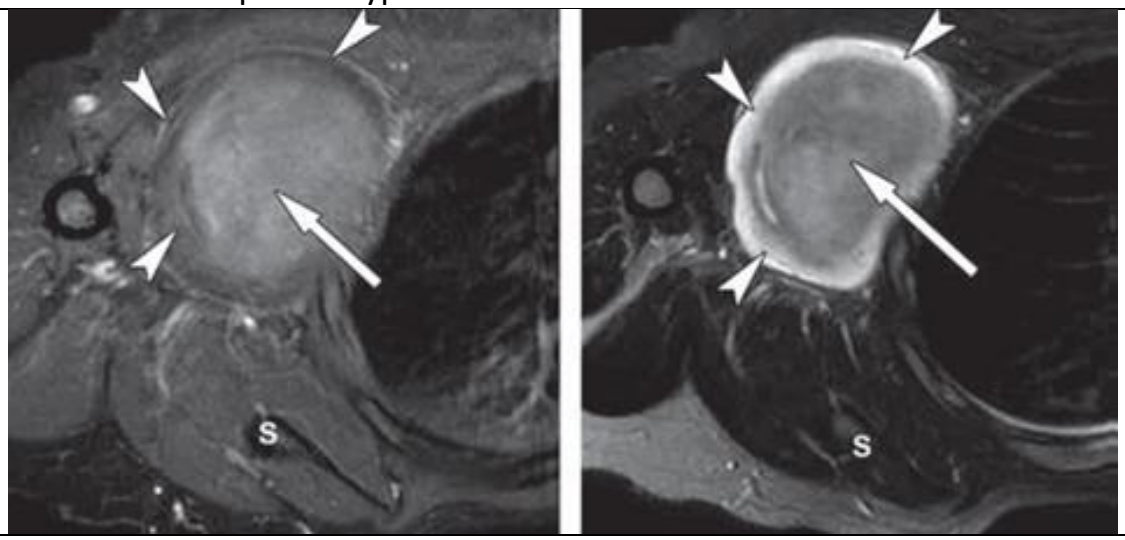
Neurofibromas are benign peripheral nerve sheath tumours.
Age = 20 and 30
Sex: no sex predilection

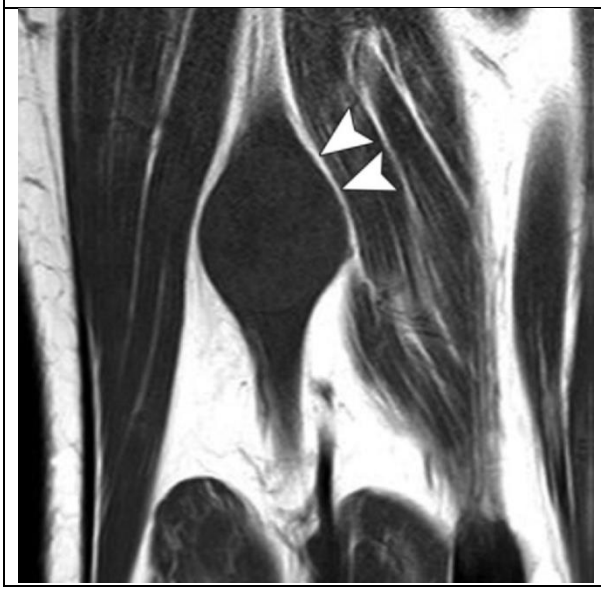
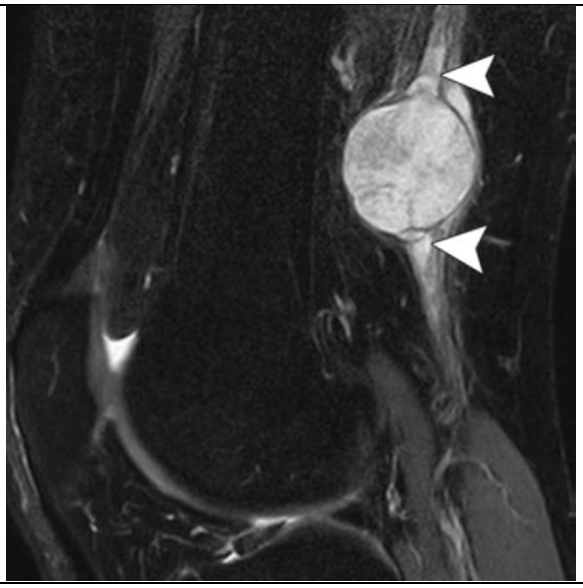
Associated with NF-1

Types: localized (90%), diffuse, and plexiform lesions

Imaging Findings:

- Fusiform shape
- **T2: Target-like appearance =**
    - Central zone of low signal of a highly cellular component
    - Peripheral zone of high signal of abundant stromal material.
- **T1+C: Target-like appearance =**
    - Central marked enhancement
    - Peripheral hypo enhancement



“Split Fat Sign”	**“String Sign”**
The lesion is surrounded by a rim of fat.	The entering and exiting nerve roots are visualized at both ends of a vertically oriented fusiform mass
	

b) Schwannoma

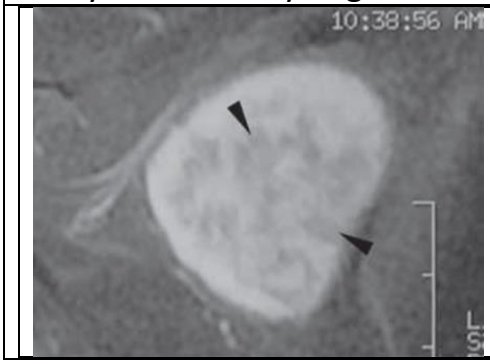
- Schwannomas are benign tumours of schwann cell origin and are the most common tumour of peripheral nerves.
- Most schwannomas are solitary (90%) and sporadic,
- Multiple schwannomas are characteristic of NF2.

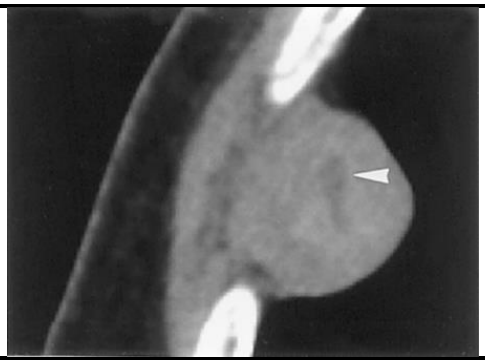
Locations:

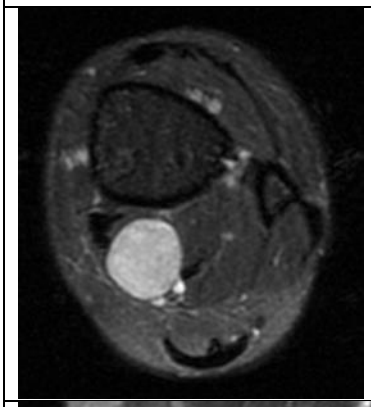
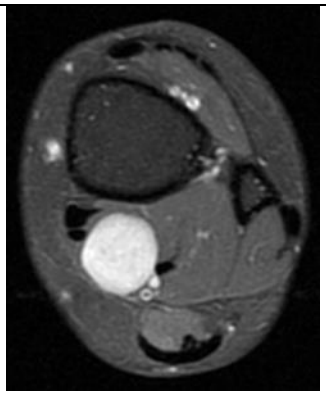
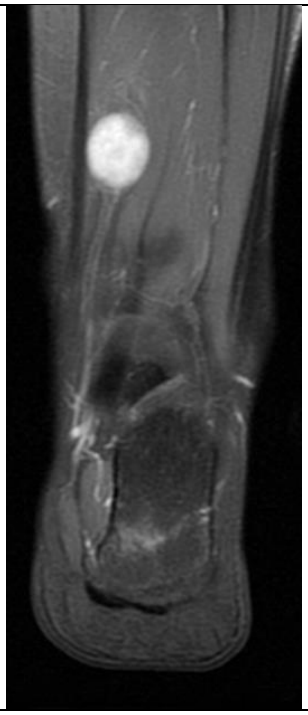
- Cranial nerves. Any cranial nerve may be involved, except CNI and CN2 which lack sheaths composed of schwann cells. The most commonly involved cranial nerves include:
- CN VIII (acoustic neuroma), most commonly the superior portion of vestibular nerve (most common)
- CN V (2nd most common)
- CN VII (3rd most common)
- Jugular foramen (CN IX, X, XI)
- Spinal nerve roots
- Flexor surfaces of upper and lower limbs (specifically ulnar and peroneal nerves)
- Posterior mediastinum
- Retroperitoneum
- Intracerebral (very rare)

Imaging Findings:

- Well defined homogeneous mass.
- T1: Iso – hypointense
- T2: Marked hyperintense
- Small tumors => Intense homogenous enhancement
- Large tumors => Heterogeneous enhancement + cystic changes
- Cystic and fatty degeneration are common





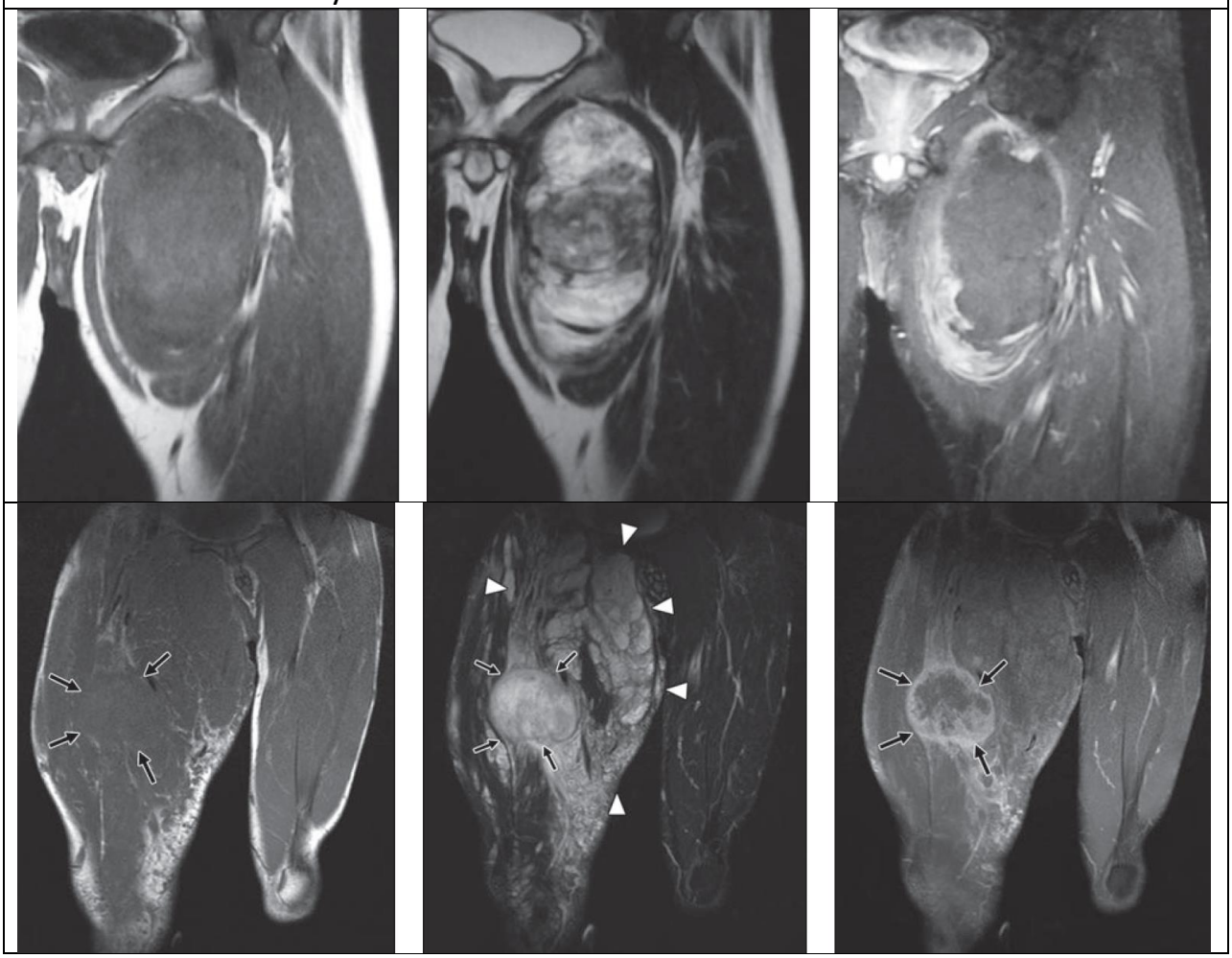
Posterior Tibial Nerve Schwannoma	
Axial & Coronal STIR	Axial & Coronal T1 +C FS
	
	

c) Malignant Peripheral Nerve Sheath Tumors

- Rare tumors; 3–10% of all soft-tissue sarcomas
- 25–50% of cases, malignant peripheral nerve sheath tumors are associated with neurofibromatosis 1.
- Malignant peripheral nerve sheath tumors have a tendency to recur locally and to metastasize and are known to be highly malignant.

❖ ***MRI features that helped to distinguish malignant peripheral nerve sheath tumors from neurofibroma:***

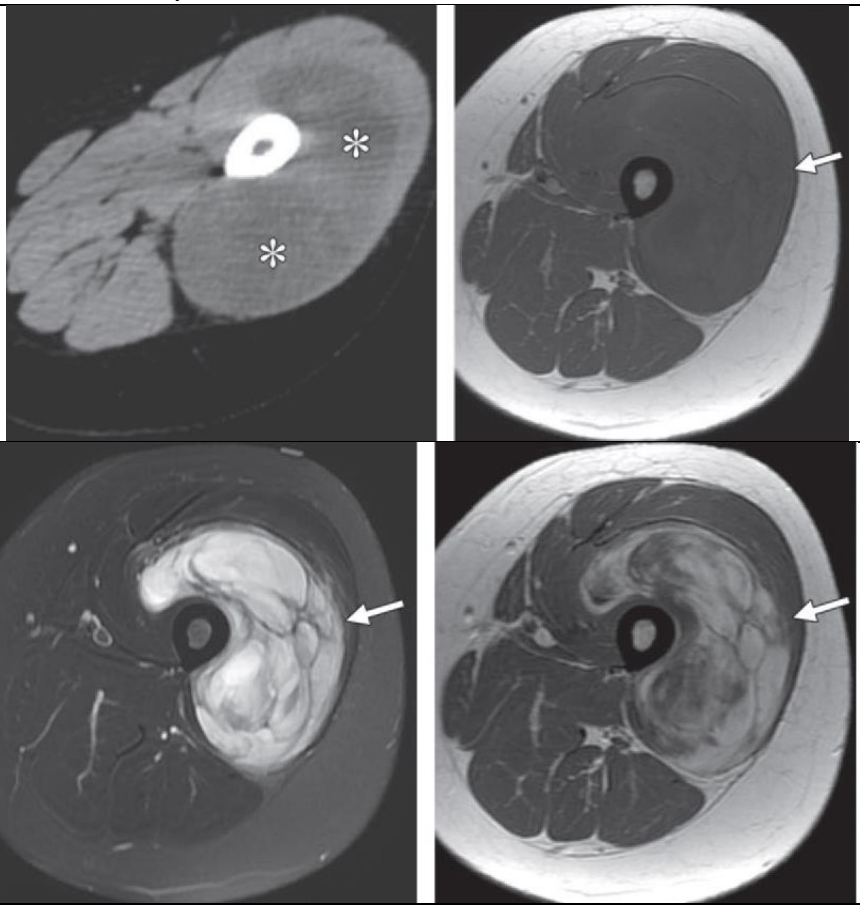
- Increased largest dimension of the mass
- Peripheral enhancement pattern
- Perilesional edema like zone.
- Intra-tumoral cystic lesion.



3) Myxoid Liposarcoma (See previous chapter)

4) Myxofibrosarcoma
= Myxoid Malignant Fibrous Histiocytoma

- Myxoid Malignant Fibrous Histocytoma MFH, is now termed "myxofibrosarcoma" by the WHO
- Myxofibrosarcoma is among the most common sarcomas in ***elderly patients***.
- ***NO Fat*** in myxofibrosarcomas, allowing their differentiation from myxoid liposarcomas
- Post-contrast heterogeneous nodular and peripheral enhancement is often seen in the solid components

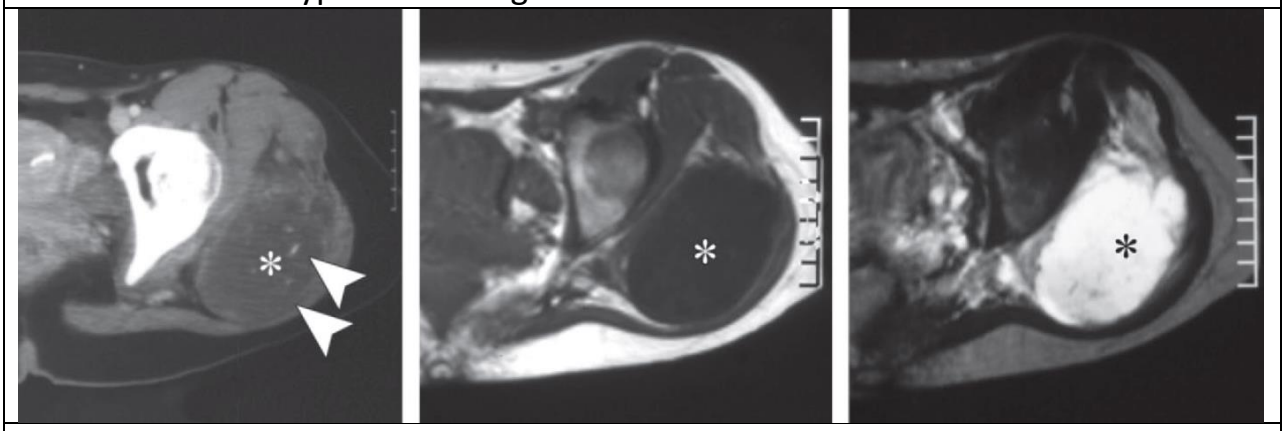


5) Extraskeletal Myxoid Chondrosarcoma

- Rare (<2% of all soft-tissue sarcomas)
- Age: Adults – mean age 50y
- Areas of chondroid matrix mineralization

Imaging Findings:

- CT: Chondroid matrix mineralization (arrowheads)
- T1: Hypointense signal
- STIR: Marked Hyperintense signal

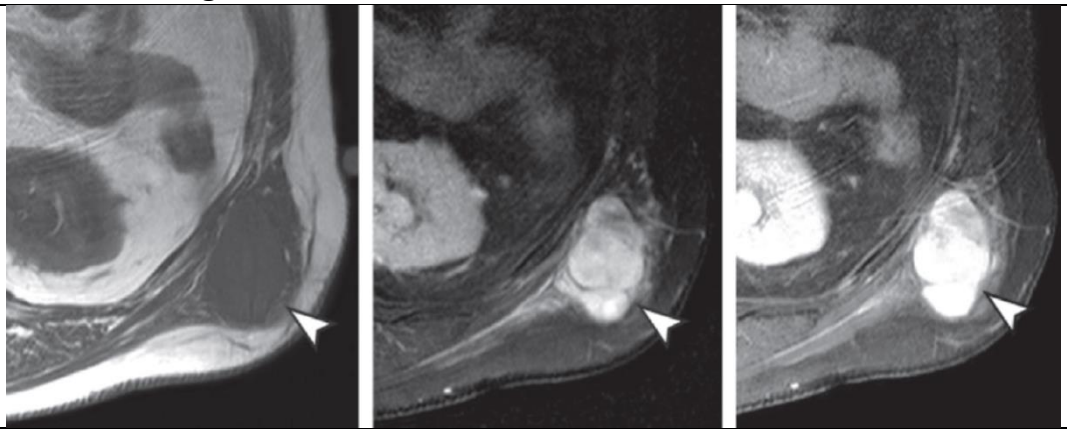


6) Myxoid Leiomyosarcoma

- Rare variant of leiomyosarcoma
- Location: Genital tract (uterus), retroperitoneum, and, less commonly, the thigh

Imaging Findings:

- T1: hypointense signal
- STIR: Marked hyperintense signal
- T1+C FS: Heterogeneous enhancement

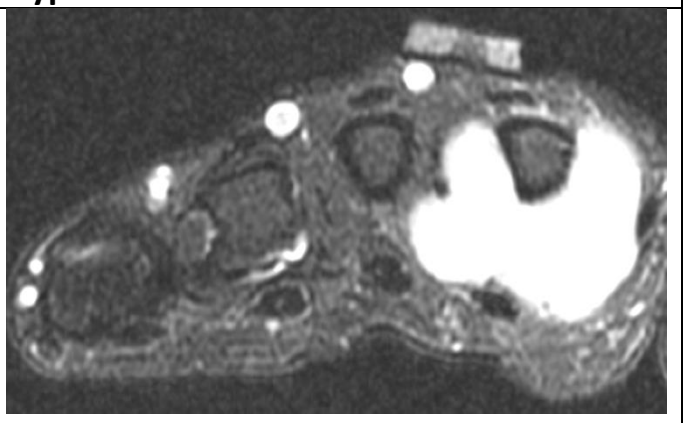


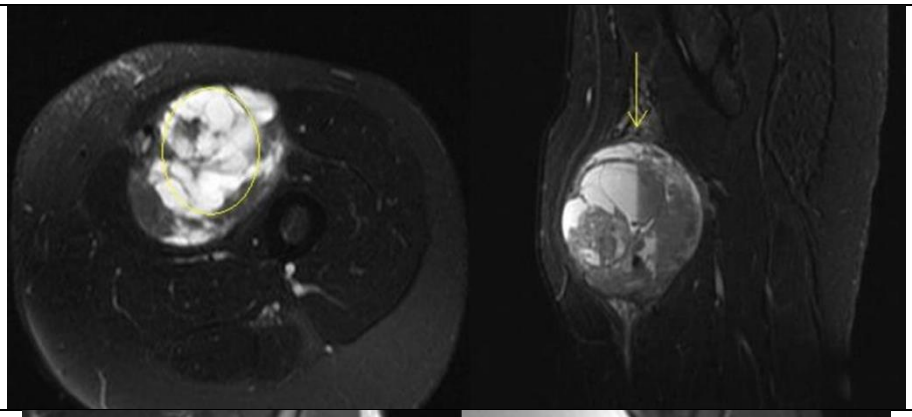
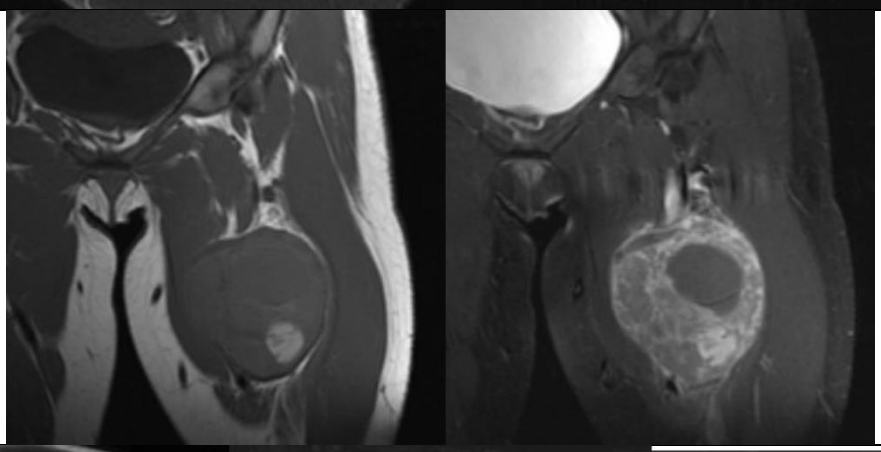
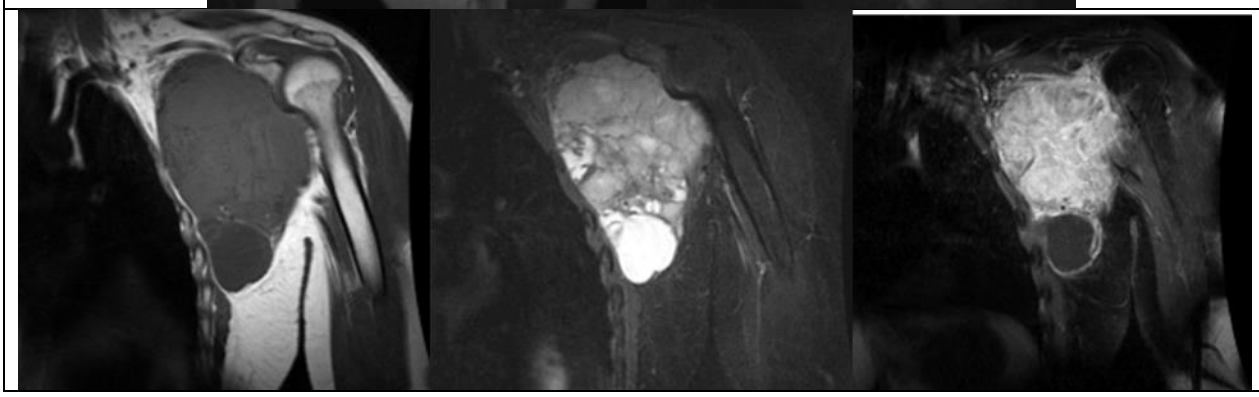
7) Synovial Sarcoma

- Synovial sarcoma is the most common ***pediatric soft-tissue sarcoma*** after rhabdomyosarcoma
- Despite the name, synovial sarcomas do not arise from synovial tissue.
- They usually originate near a joint, not from an intra-articular location.
- Location: most common in the lower extremity.
- **Age: 15-35y**

Imaging Findings:

- Multilobulated mass
- 30% contain amorphous calcifications
- T1: isointense to muscle
- T2:
  - **"Triple sign":** The mass contains areas of intermediate+hyperintense+hypointense signal, which indicate the variety of tumor contents, including cellular elements, cysts, hemorrhage, necrosis, calcifications and/or fibrosis.
  - **Fluid-fluid levels** are due to cystic degeneration and internal hemorrhage.
  - **"Bowl of grapes":** Internal septations result in multiple cystic areas
- +C: Heterogeneous contrast enhancement.
- The marrow signal is normal, indicative of bony sparing

Calcification:	**Hyperintense T2**
	

Fluid/Fluid levels




8) Vascular Lesions

Mulliken & Glowacki Classification
of vascular malformations

Simple	Complex	
	Regional	**Diffuse**
Slow flow	Sturge-Weber	Mafucci
Capillary	Klippel-Trénaunay	Solomon
Lymphatic	F.P. Weber	Proteus
Venous	Syndromes often associated with osseous hypertrophies	
Fast flow		
Arterial: Aneurysm, Coarctation, Ectasy		
Arteriovenous Fistulae (with one or more shunts)		
Arteriovenous Malformations (with a nidus of multiple shunts)		

ISSVA Classification of Vascular Tumors and Malformations

- Tumors
  - Infantile hemangioma
  - Congenital hemangioma
    - Rapidly involuting congenital hemangioma
    - Noninvoluting congenital hemangioma
  - Kaposiform hemangioendothelioma
  - Tufted angioma
  - Hemangiopericytoma
  - Pyogenic granuloma
  - Spindle cell hemangioendothelioma
- Malformations
  - Simple (ie, venous, lymphatic, capillary, and arterial)
  - Combined (eg, arteriovenous)

Syndromes Associated with Vascular Tumors and Malformations

- Tumors
  - Infantile hemangioma, PHACE syndrome
- Malformations
  - Low-flow
    - Sturge-Weber syndrome, Klippel-Trénaunay syndrome, Proteus syndrome, Cutis marmorata telangiectatica congenita, Adams-Oliver syndrome, blue rubber bleb nevus syndrome (Bean syndrome), Maffucci syndrome, Gorham-Stout syndrome
  - High-flow
    - Bonnet-Dechaume-Blanc syndrome (Wyburn-Mason syndrome), Parkes Weber syndrome, Rendu-Osler-Weber syndrome (hereditary hemorrhagic telangiectasia), Cobb syndrome, Cowden syndrome, Ehlers-Danlos syndrome (type 4)

A- Vascular Tumors

i) Infantile or Juvenile Hemangiomas = Common Hemangiomas of Infancy

- Most common vascular tumors of infancy
- F>M

Location:

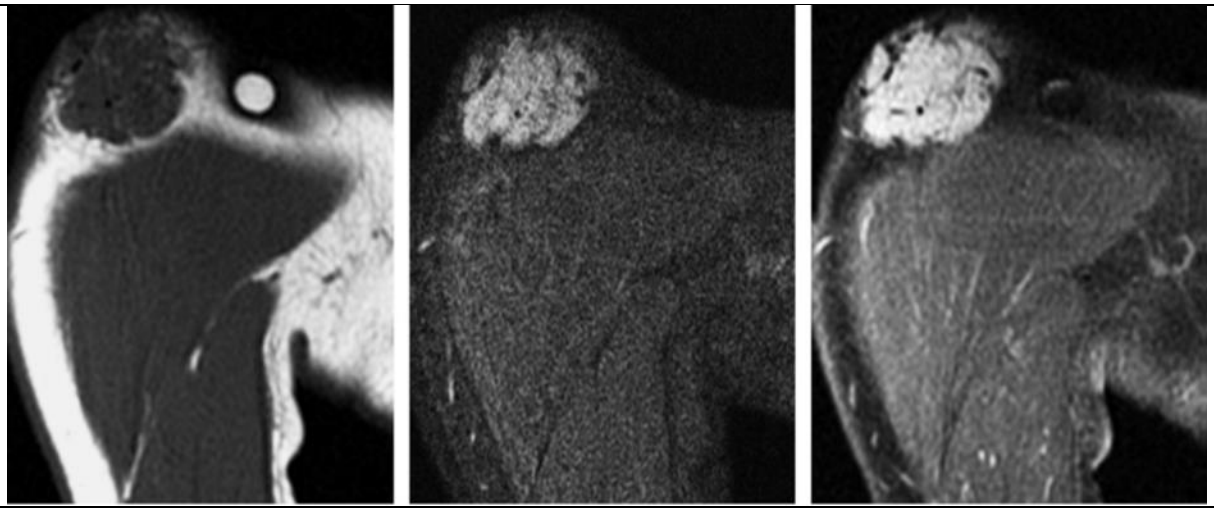
- Face And Neck (60% Of Cases),
- Trunk (25%)
- Extremities (15%)
- Multiple in about 20% of Cases

2 Biologic Phases:

- Proliferative phase is characterized by rapid endothelial growth in the first few months of life, stabilizing in size at about 9–10 months of age.
- Involuting phase then continues slowly for the next several years, during which time the hemangioma is replaced by fibrofatty tissue, with the process usually being completed by 7–10 years of age.

Imaging Findings:

- A well circumscribed lobulated lesions
- T1: hypo- to isointense relative to muscle
- T2: hyperintense
- T1+C: early and homogeneous enhancement after gadolinium-based contrast material administration.

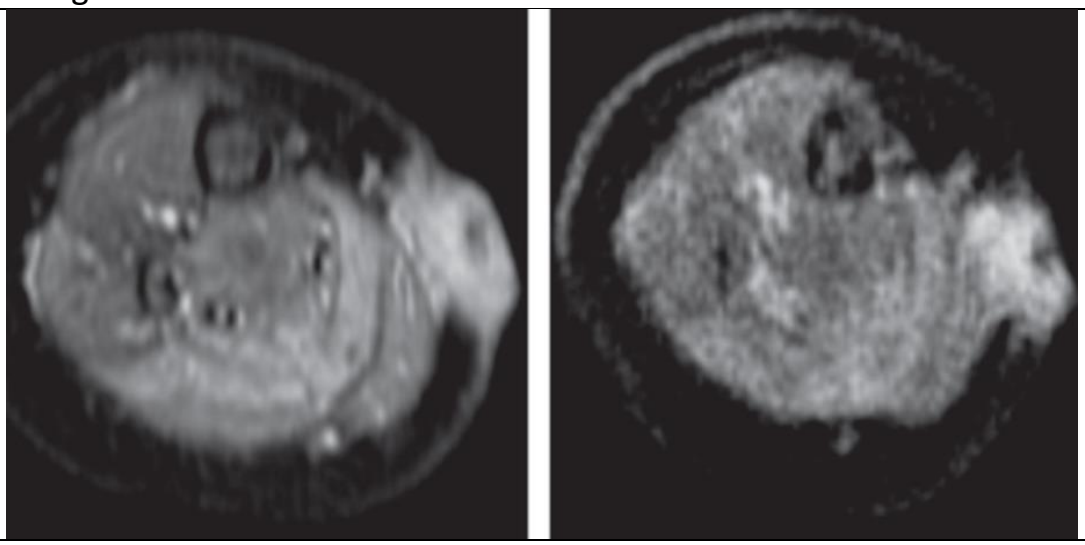


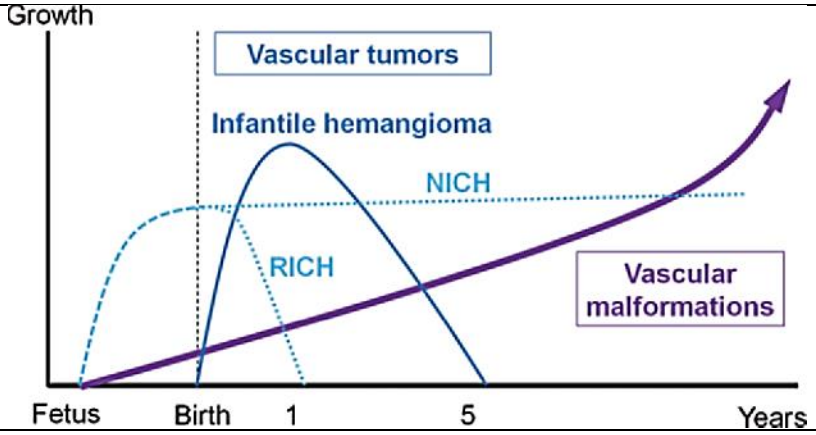
ii) Congenital Hemangioma

Two types:

- **Rapidly involuting congenital hemangioma (RICH):** is a hemangioma- like lesion that at birth is already at or past the peak of its proliferative phase and involutes completely by 14 months of age.
- **Noninvoluting congenital hemangioma (NICH):** grows proportionally with the child without undergoing involution

- MR imaging appearances of rapidly involuting congenital hemangioma and noninvoluting congenital hemangioma are similar to that of common infantile hemangiomas.



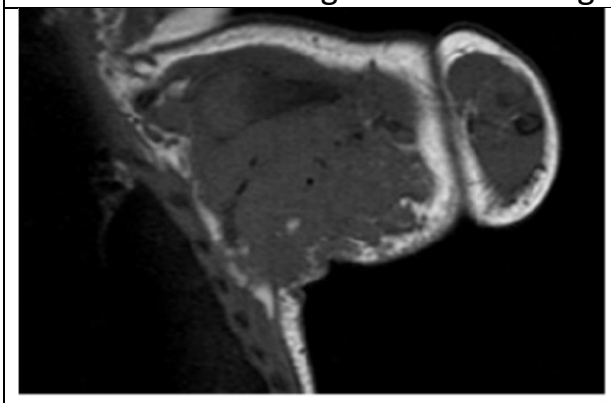


iii) Kaposiform Hemangioendothelioma

- A vascular neoplasm of infancy that can be distinguished from common hemangiomas of infancy at pathologic analysis.
- The most relevant clinical finding (>50% of cases) is an association with Kasabach-Merritt phenomenon, a coagulopathy characterized by profound thrombocytopenia.
- Kasabach-Merritt phenomenon is secondary to kaposiform hemangioendothelioma in 90% of cases

<u>kaposiform hemangioendothelioma differ from common infantile hemangiomas include :</u>

- Ill-defined margins
- Involvement of multiple tissue planes
- Cutaneous thickening
- Stranding of the subcu-taneous fat
- Hemosiderin deposits
- Less prominent
- Superficial vessels
- Destructive changes or remodeling of adjacent bone



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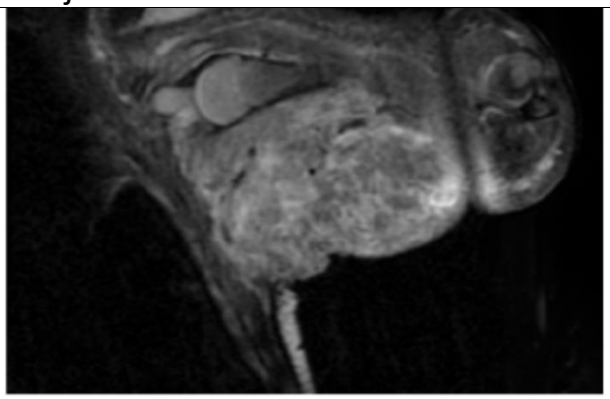

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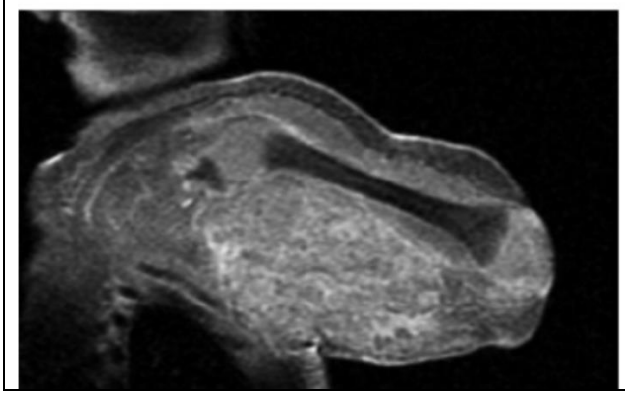


Figure 10. Kaposiform hemangioendothelioma in a 5-day-old male infant who presented with a large left arm mass and Kasabach-Merritt phenomenon. **(a)** On a coronal T1-weighted MR image, the mass is isointense relative to muscle. **(b)** Coronal fat-suppressed T2-weighted MR image shows the lesion with heterogeneous signal intensity. **(c)** Coronal gadolinium-enhanced fat-saturated spoiled gradient-recalled echo MR image shows the lesion with inhomogeneous contrast enhancement.

B- Vascular Malformations

Simple Vascular Malformations:

- Capillary
- Lymphatic
- Venous

Combined Vascular Malformations:

- Arteriovenous malformations (AVM).
- Arteriovenous fistula (AVF).
- Capillary-Venous malformation
- Lymphatic-venous malformation.
- Capillary-lymphatic-venous malformation

High-flow Vascular Malformations

- Arteriovenous malformations (AVM).
- Arteriovenous fistula (AVF).

Low-flow Vascular Malformations:

- Venous.
- Lymphatic.
- Capillary.
- Capillary-Venous malformation
- Lymphatic-venous malformation.
- Capillary-lymphatic-venous malformation

i. Arteriovenous Malformations

Characterized by:

- Abnormal network of tortuous and dysplastic vascular channels = nidus
- Feeding arteries
- Draining veins
- Absence of a normal capillary bed.
- Arteriovenous malformations may enlarge acutely due to trauma, puberty, pregnancy, or iatrogenic trauma.

MR imaging

- High-flow
- Enlarged feeding arteries
- Draining veins
- Tortuous signal void patterns of variable caliber on spin-echo images and high-signal intensity foci on gradient-echo images.
- MR imaging is useful in assessing lesion extent, degree of soft-tissue overgrowth, and possible bone involvement.
- MR angiography can show the arteries supplying this vascular malformation in great detail

ii. Arteriovenous Fistula

- is usually a single large vascular channel between an artery and a vein.
  - Congenital, usually in the head and neck,
  - Secondary to penetrating injury, including venous puncture
- MR imaging may show the arterial and venous components of the fistula as large signal voids on spin-echo images and as high-signal-intensity foci on gradientecho images, without a well-defined mass

iii. Venous Malformations

- Most common of all vascular malformations.
- Manifest as localized, solitary or multiple masses that are soft and fluctuant and that expand with Valsalva maneuver, after compression, and with gravity (in the dependent limb).
- If venous malformations are superficial, there is commonly a blue-purple discoloration to the overlying skin.
- They may also manifest as diffuse dilatation and varices involving major veins.

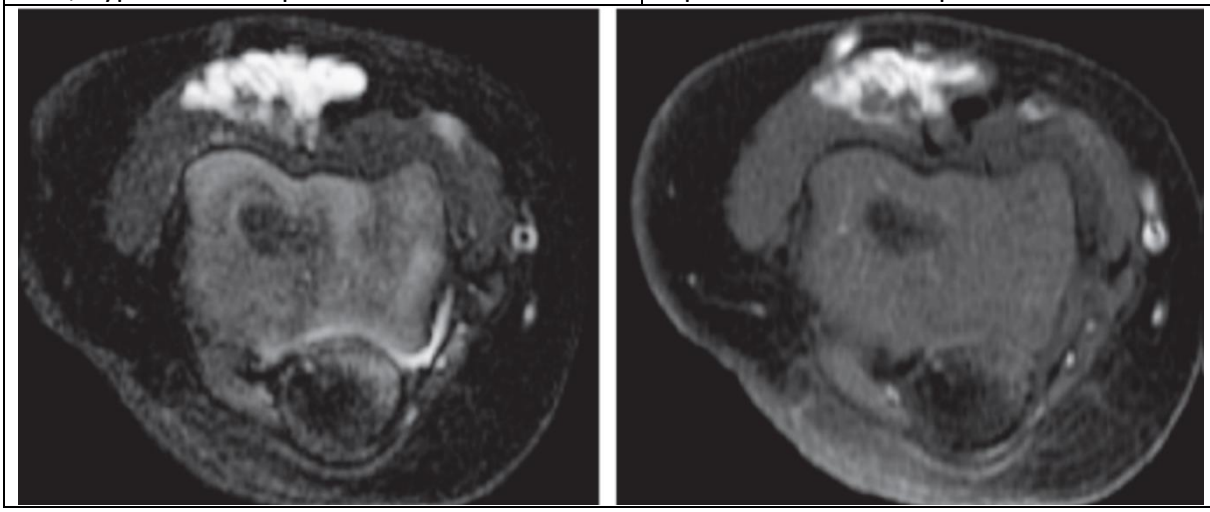
Location:

- Head and neck (40%)
- Extremities (40%)
- Trunk (20%)

MR imaging:

- At venous malformations appear as dilated veins more commonly, as lobulated multilocular masses, with the locules representing venous lakes separated from each other by interstitial septa
- T1: iso- to hypointense
- T2: hyperintense
- Enhance after gadolinium-based contrast material administration.
- Gradient-echo imaging shows an absence of flow.
- Phleboliths appear as signal void foci with all sequences,
- Thrombi appear as foci without enhancement after gadolinium-based contrast material administration.

Axial fat-suppressed T2-weighted MR image shows a high-signal-intensity lobulated Mass. The mass has a multilocular appearance due to hyperintense venous spaces separated by thin, hypointense septa	Axial gadolinium-enhanced fat-suppressed T1 weighted MR image shows almost complete enhancement of the mass. The intralesional areas of low signal intensity (also seen in a) represent thrombi or phleboliths.

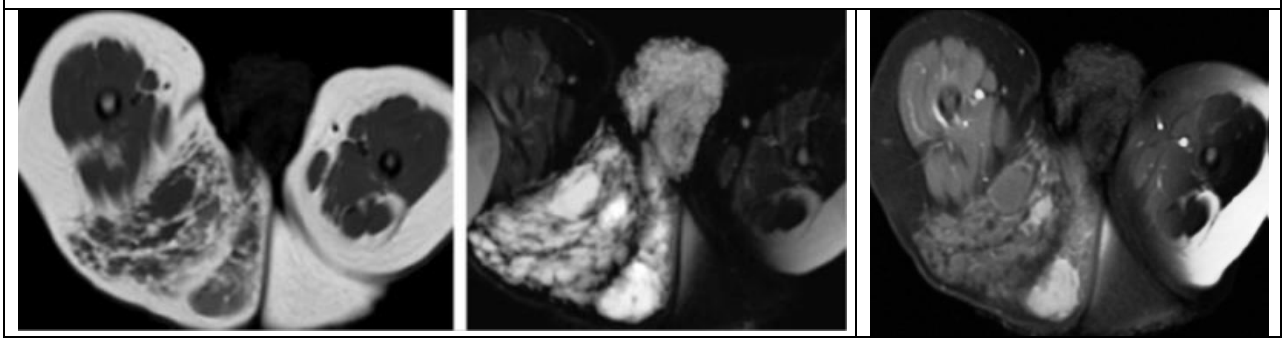


iv. Lymphatic Malformations

- known as Cystic hygromas and lymphangiomas
- Lymphatic malformations may be composed of very small cystic components a few millimeters in size (microcystic) or of larger cystic spaces (macrocystic).
- Lymphatic malformations are commonly mixed with other vascular malformations.
- 75% of cases are found in the head and neck

MRI:

- Multiseptated cystic mass that can infiltrate surrounding tissues.
- There may be associated hypertrophy of the affected body part.
- T1: The cysts are typically hypointense
- T2: hyperintense
- More heterogeneous signal intensity can be seen within cysts with proteinaceous content or prior hemorrhage.
- The cysts do not characteristically enhance, although the septa, which are vascularized, show contrast material uptake.
- There may also be enhancement of the venous component in mixed malformations



v. Capillary Malformations

- Characterized by a collection of vascular channels in the dermis, are also known as port-wine stains and generally do not require imaging because the diagnosis is made clinically.
- MR imaging, the capillary malformations themselves are usually not identifiable, although increased thickness of the subcutaneous fat and prominent veins may be found in some cases

C- Syndromes Associated with Vascular Tumors and Malformations

Syndromes Associated with Vascular Tumors and Malformations

Tumors

Infantile hemangioma, PHACE syndrome

Malformations

Low-flow

Sturge-Weber syndrome, Klippel-Trénaunay syndrome, Proteus syndrome, Cutis marmorata telangiectatica congenita, Adams-Oliver syndrome, blue rubber bleb nevus syndrome (Bean syndrome), Maffucci syndrome, Gorham-Stout syndrome

High-flow

Bonnet-Dechaume-Blanc syndrome (Wyburn-Mason syndrome), Parkes Weber syndrome, Rendu-Osler-Weber syndrome (hereditary hemorrhagic telangiectasia), Cobb syndrome, Cowden syndrome, Ehlers-Danlos syndrome (type 4)

i) Klippel-Trénaunay Syndrome

(a) Capillary malformations or patchy port wine stains covering a large area of the affected limb that may involute by the time the patient reaches 20–30 years old
(b) Congenital varicose veins or venous malformations characterized by abnormal, dilated blood vessels called lateral mega veins that develop on the lateral aspect of the affected limb
(c) bone and soft-tissue hypertrophy resulting from overgrowth.

Major Imaging Finding

- Overgrowth of subcutaneous soft tissues in the lower limbs.
- Vascular overgrowth appears as an area with slow uptake of contrast material in the delayed phase, a finding indicative of low flow.
- The affected limb is usually thicker and longer than the non affected limb

Complications:

- Deep vein thrombosis
- Pulmonary embolism
- Infection or sepsis
- Chronic coagulopathy
- Bloody stools
- Hematuria
- Epistaxis

ii) Blue Rubber Bleb Nevus Syndrome

- ***Multiple cutaneous venous malformations*** (blue to black, rubbery nevi) that range from 0.1 cm to 5.0 cm in diameter.
- ***Multiple venous malformations of GIT.***

Complications:

- Gastrointestinal hemorrhage and bloody stools.
- Anemia, chronic coagulation disorders,
- Hemothorax
- Tumors
- Hypercalcemia
- Vascular malformations of internal organs.

Numerous masses and multiple phleboliths in the wall of the colon (arrows) and liver parenchyma (arrow head).

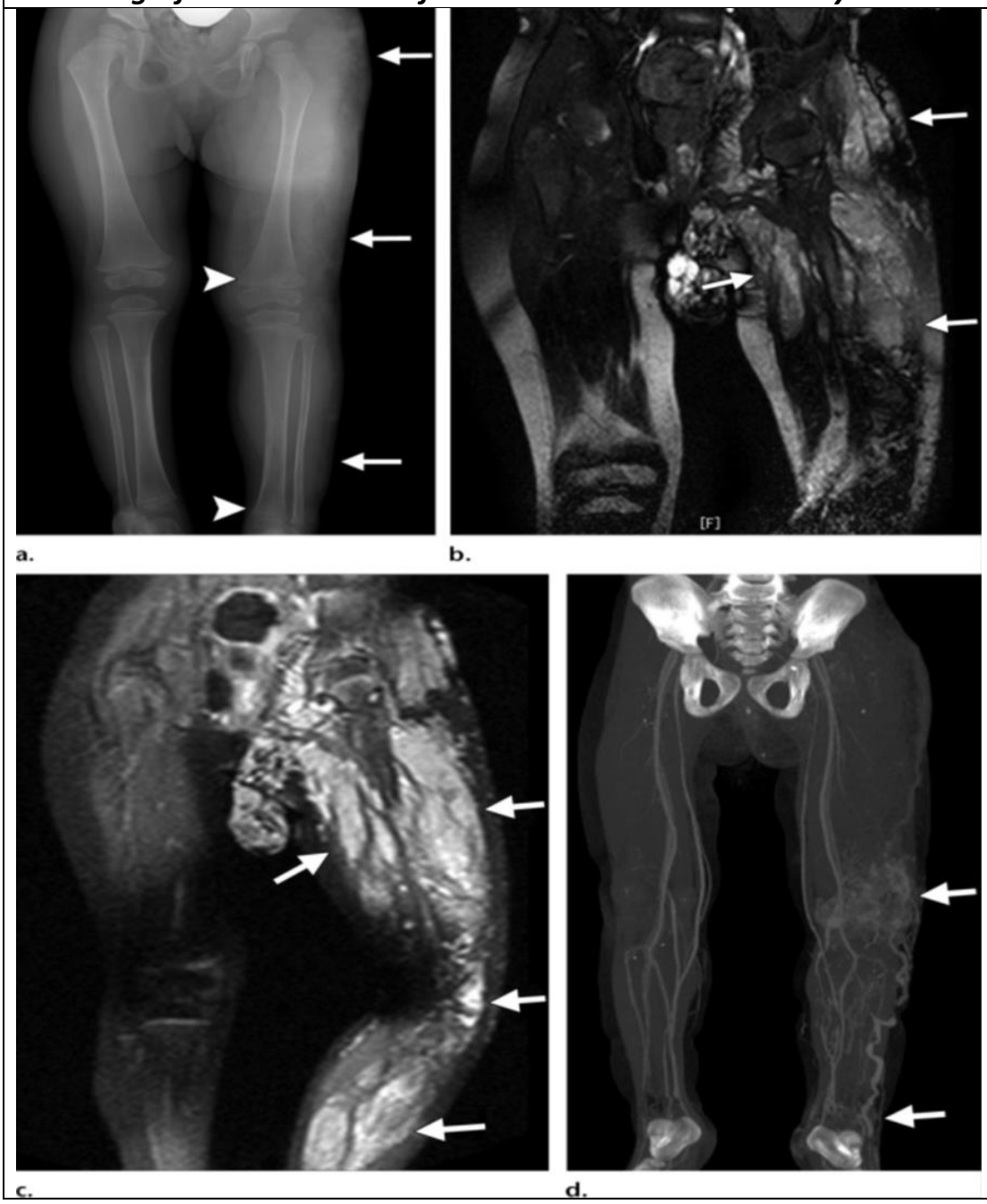
a. b.

iii) Parkes Weber Syndrome

Characterized by overgrowth of the affected limb with small diffuse arteriovenous fistulas or shunts.

Parkes Weber syndrome may be confused with Klippel-Trénaunay syndrome:

- ***Low-flow vascular malformations => Klippel-Trénaunay syndrome.***
- ***High-flow vascular malformations => Parkes Weber syndrome***



iv) Rendu-Osler-Weber Syndrome (Hereditary Hemorrhagic Telangiectasia [HHT])

- It is a genetic, autosomal dominant disorder
- characterized by dilatation of small skin and mucosal blood vessels, which leads to epistaxis and hemorrhage into GIT.

Diagnosic Criteria for Rendu-Osler-Weber Syndrome

Spontaneous, recurrent nose bleeds (epistaxis)
Multiple telangiectases in the lips, oral cavity, fingers, or nose
Visceral lesions such as pulmonary, hepatic, cerebral, and spinal arteriovenous malformations and fistulas
A first-degree relative with HHT according to these criteria

Rendu-Osler-Weber syndrome is

- Definite if three criteria are present,
- Possible or suspected if two criteria are present,
- Unlikely if less than two criteria are present.

AVM in Lung

AVM in Liver

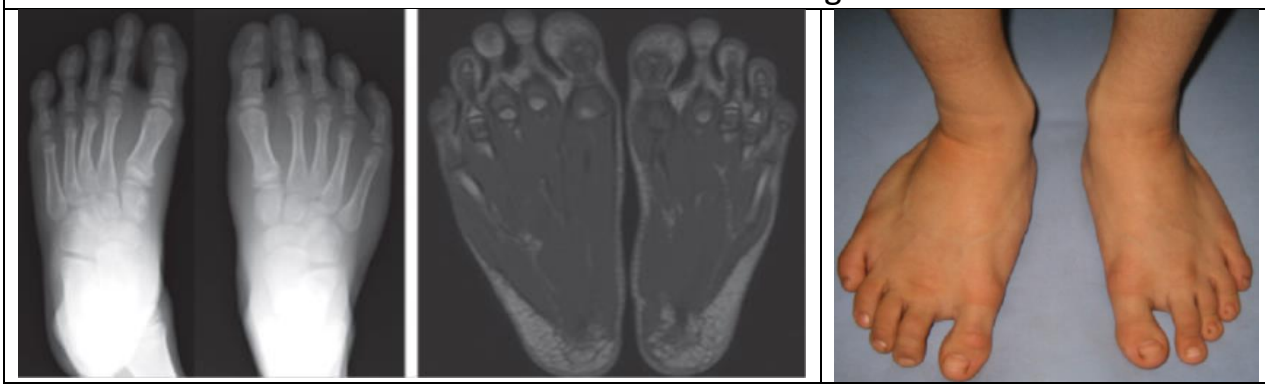
v) Proteus Syndrome

Diagnostic Criteria for Proteus Syndrome
Group A
Connective tissue nevus
Group B
Epidermal nevus
Disproportionate area of overgrowth (one or more)
Bilateral ovarian cystadenomas or a parotid monomorphic adenoma before the end of the 2nd decade of life
Group C
Lipomata or localized absence of fat
Vascular malformations (eg, capillary, venous, lymphatic)
Lung cysts
Facial malformations
Note.—A diagnosis of Proteus syndrome is made in patients with one criterion from group A, two criteria from group B, or three criteria from group C.

Imaging Findings:

- Asymmetric bone
- Soft-tissue overgrowth
- Hypertrophy of fat
- Skull enlargement,
- Thickening of digestive tract walls,
- Cystic emphysematous alteration of the lung.

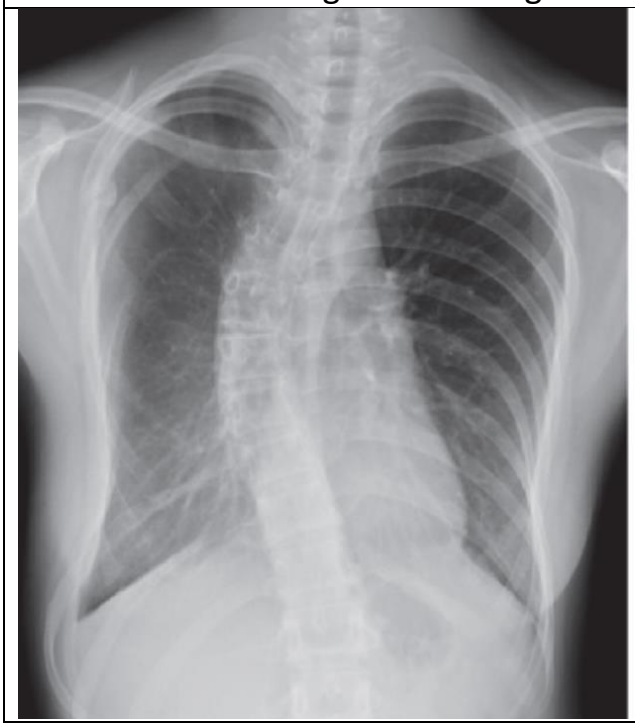
Proliferation of muscle and subcutaneous fat in the right foot.

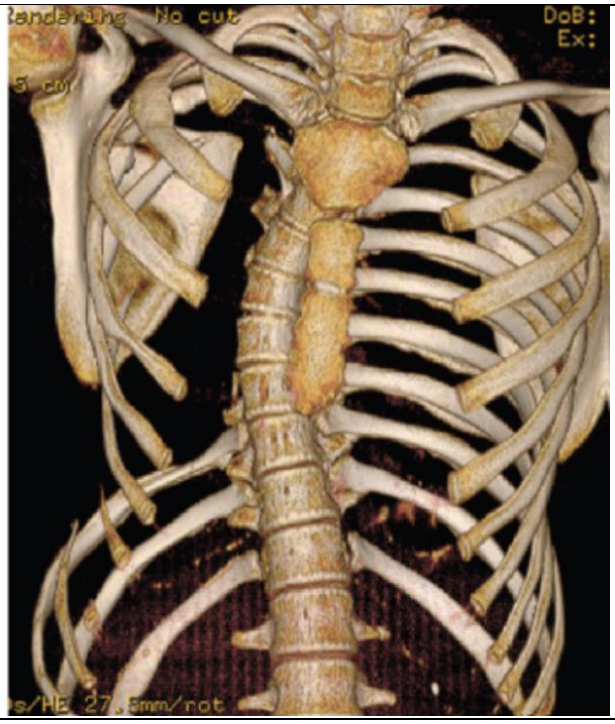


vi) Gorham-Stout Syndrome = Vanishing bone syndrome

- Characterized by cryptogenic bone lysis with lymphatic malformations.
- When an osteolytic lesion of unknown cause is identified, Gorham- Stout syndrome should be considered.

- Absence of the right 5th through 9th ribs and scoliosis.





vii) Vascular Metameric Syndrome

- **<u>Wyburn-mason Syndrome</u>** = Cerebral Arteriovenous Metameric Syndrome (CAMS):
  - Brain + Facial arteriovenous malformation or fistula => same body segment
- **<u>Cobb syndrome =</u>** Spinal arteriovenous metameric syndrome (SAMS):
  - Spinal + Cutaneous arteriovenous malformation or fistula => same body segment

viii) PHACE Syndrome

PHACE syndrome is a neurocutaneous syndrome of unknown etiology without familial associations but with a strong female predominance.

The PHACE acronym lists the most common anomalies in the syndrome:

P - posterior fossa and brain anomalies
H - hemangiomas
A - arterial or cerebrovascular anomalies
C - cardiac and aortic anomalies
E - eye anomalies
S is added (PHACES) for sternal anomalies.

Kasabach-Merritt Syndrome and Kasabach- Merritt–like Phenomenon

- Characterized by pediatric hemangiomas => complicated by a decreased number of platelets; hemolytic anemia; and a coagulation abnormality causing hemorrhage, infections, and multiple organ failure, with death occurring in 12%–24% of patients.

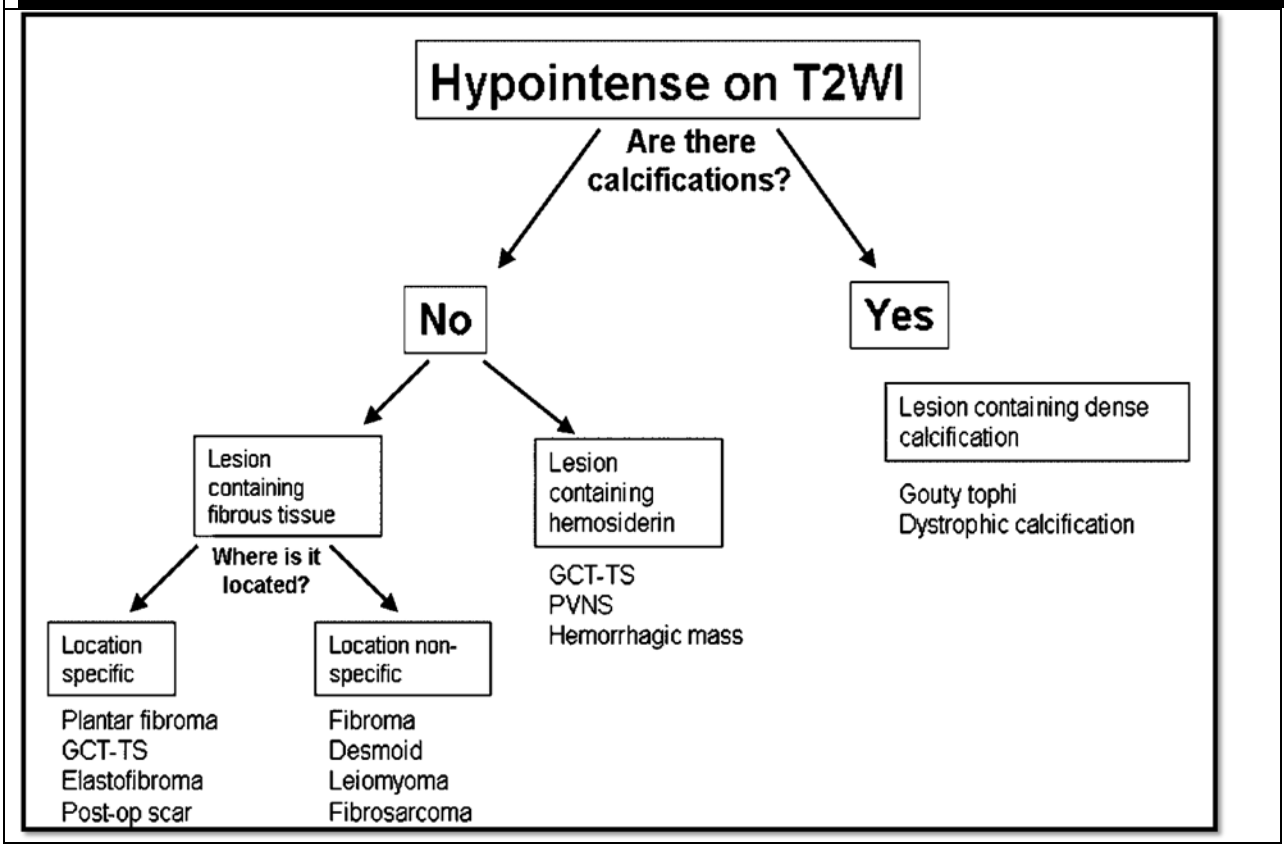
Comparison of Kasabach-Merritt Syndrome and Kasabach-Merritt–like Phenomenon

Condition	Pathophysiologic Characteristics	Cause	Treatment
Kasabach-Merritt syndrome	Blood coagulation factors and platelets are trapped between vascular tumor cells (entrapment coagulopathy)	Tufted angioma, kaposiform hemangioendothelioma	Resection; corticosteroid, chemo-, interferon, and radiation therapy; embolization
Kasabach-Merritt–like phenomenon	Blood coagulation factors are consumed after hemorrhage (consumptive coagulopathy)	Venous and other types of malformation	Blood coagulation factors

	Low Flow	High Flow
Leg	Klippel-Trénaunay Proteus Syndrome	Park-Weber Syndrome
GIT	Blue-Ruber-Bleb Nevus	Rendu-Osler-Weber (HHT)
CNS	Sturge-Weber Syndrome	Metameric Syndrome (CAMS/SAMS)

III- Hypointense T2

T2 hypointense	
Lesion containing fibrosis	Scar tissue, plantar fibroma, elastofibroma, desmoid, fibrosarcoma, GCT of tendon sheath, lymphoma (occasionally)
Lesion containing dense calcification	Gouty tophi, dystrophic calcification
Lesion containing hemosiderin	GCT of tendon sheath



A- Fibroblastic/Myofibroblastic Tumors

Benign

- Nodular fasciitis
- Proliferative fasciitis and proliferative myositis
- Myositis ossificans
- Elastofibroma
- Myofibroma/myofibromatosis
- Fibromatosis colli
- Fibroma of tendon sheath
- Desmoplastic fibroblastoma
- Calcifying fibrous tumor
- Angiofibroma
- Angiomyofibroblastoma
- Gardner fibroma
- Giant cell angiofibroma

Intermediate (locally aggresive)

- Superficial fibromatosis
  - (plantar/palmar)
- Desmoid-type fibromatosis
- Lipofibromatosis

Intermediate (rarely metastasizing)

- **Solitary fibrous tumor- SFT- (Hemangiopericytoma)- HPM**
- Myofibroblastic inflammatory tumor
- Myofibroblastic sarcoma
- Dermatofibrosarcoma protuberans - **DP-**

Malignant

- Adult Fibrosarcoma
- Myxofibrosarcoma (previously myxoid malignant fibrous histiocytoma)

B-Fibrohistiocytic Tumors

So-called fibrohistiocytic	
Benign	GCT of tendon sheath, diffuse-type giant cell, deep benign fibrous histiocytoma
Intermediate (rarely metastasizing)	GCT of soft tissues

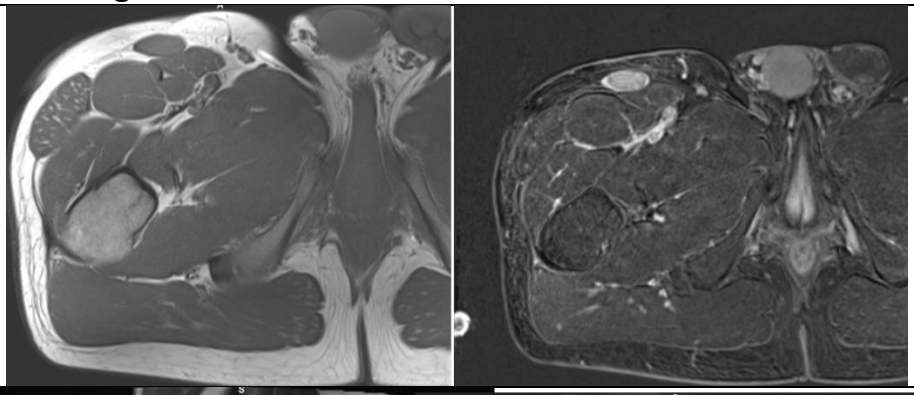
A- Fibroblastic/Myofibroblastic Tumors

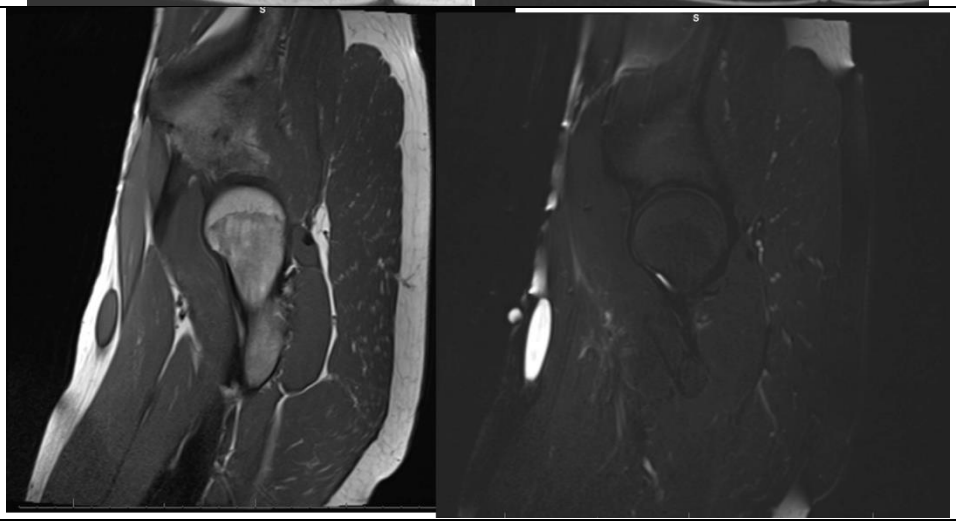
1) Nodular Fasciitis

- Subcutaneous lesions tend to belong to a myxoid subtype
- Age: Nodular fasciitis is more commonly seen in young adults
- Location: upper extremities > trunk > head and neck > lower extremities

Imaging findings:

- Nodular fasciitis may be categorized as myxoid, cellular, or fibrous. This histologic diversity likely accounts for the variable MR imaging appearance of the lesions:
- T1: homogeneous SI comparable with normal muscle
- T2:
    - Myxoid type => high SI
    - Collagenous / fibrous type => Low SI
- T1+C: they usually show mild to moderate enhancement, which is diffuse but slightly inhomogeneous





2) Myositis Ossificans

- The cause of myositis ossificans is soft-tissue injury, in most cases secondary to trauma

3 components:

- Central zone of proliferating fibroblasts,
- Middle zone containing osteoblasts and foci of immature bone,
- Peripheral layer with mature bone trabeculae

Acute Phase (<2 Weeks):

- T1: the lesion may not be visible or may be poorly defined and with heterogeneous signal intensity but predominantly isointense to muscle.
- T2: usually hyperintense
- The lesion may also contain fluid-fluid levels due to prior hemorrhage.
- Associated edema of the perilesional soft tissues and in the bone marrow of any adjacent bone.

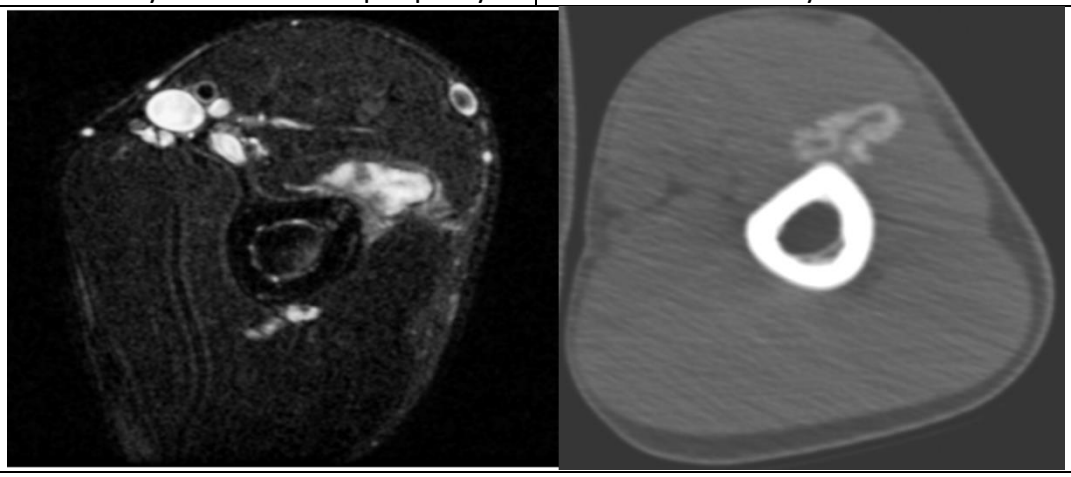
Subacute Phase (3 to 6–8 Weeks):

- Peripheral foci of low signal intensity are identifiable on both T1- and T2-weighted images, owing to bone formation.
- Enhancement with gadolinium is visible at the periphery of the lesion and in the adjacent edematous soft tissues and may mimic the appearances of an abscess or necrotic tumor.

Chronic stage (6–8 weeks or older):

- Lesion becomes better defined and the soft-tissue edema is no longer evident.
- Owing to the progression of peripheral calcification and ossification, more extensive low signal intensity is seen with all sequences.
- Areas of fat signal may also be recognized within the lesion and represents fatty marrow.

Axial T2 shows a lobulated, predominantly hyperintense, intramuscular mass and a rim of low signal intensity is noted at the periphery	Unenhanced CT scan more clearly demonstrates the characteristic peripheral mineralization of myositis ossificans



3) Myofibromatosis

- Infantile myofibromatosis (multicentric) or myofibromas (solitary) are the most common fibrous tumors in infancy.

Age:

88% of cases **children < 2 years**

60% of cases are diagnosed at birth

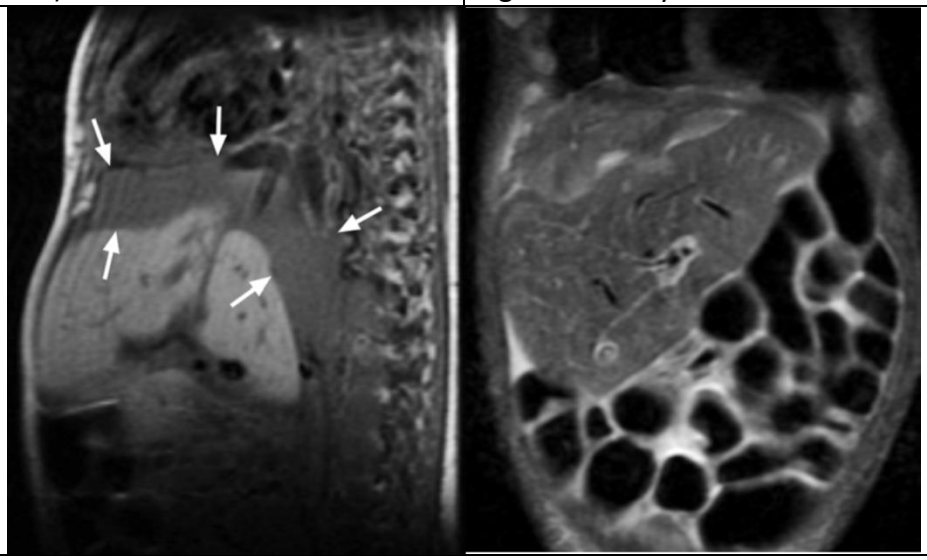
The multicentric form

- may be present in the soft tissues, bones, and viscera.
- The poorer prognosis of myofibromatosis with visceral involvement (25%–35% of multicentric cases).
- Intestinal, cardiac, and, in particular, lung lesions having a poorer outcome

Imaging Findings:

- T1: low signal intensity
- T2: more variable appearance
- These tumors have been described as showing a “target” sign after the administration of an intravenous gadolinium contrast agent, with peripheral enhancement, thought to be due to central necrosis.
- Whole-body MR imaging protocols may be useful as a screening tool for assessing multicentric involvement in myofibromatosis

Sagittal T1 shows an isointense mass inseparable from the diaphragm and contiguous to the diaphragmatic surface of the liver (arrows).	Coronal fat-suppressed T2 shows that the diaphragmatic mass is heterogeneous, containing areas of low and inter-mediate signal intensity.



4) Fibromatosis Colli

- Benign mass that arises from the sternocleidomastoid muscle.
- It is usually unilateral (Rt > Lt)
- It is thought to be a cellular scarlike reaction to injury of the sternocleidomastoid muscle in the last trimester of intrauterine growth or at the time of delivery.
- The mass is usually evident at 2 weeks after birth and may continue to increase in size for a few more weeks. It often involutes spontaneously over 4–8 months with conservative treatment.

5) Fibroma of the Tendon Sheath

- Fibroma of the tendon sheath is a rare, benign, slow-growing tumor of the extremities.
- Some controversy exists regarding whether it represents a reactive versus a neoplastic process.
- The tumor affects and adheres to the tendons, tendon sheaths, and sometimes the neurovascular

Imaging findings:

- A well-defined, lobulated, nodular mass in the vicinity of tendon sheath
- Low signal intensity with all sequences
- Minimal or no enhancement
- The tumor can sometimes be difficult to differentiate from other soft-tissue tumors commonly found in the extremities, such as giant-cell tumor of the tendon sheath and pigmented villonodular synovitis (PVNS)

6) Fibromatosis

Classification of Fibromatoses

Superficial (fascial)

- Palmar fibromatosis (Dupuytren disease)
- Plantar fibromatosis (Ledderhose disease)
- Juvenile aponeurotic fibroma
- Infantile digital fibromatosis
- Penile fibromatosis (Peyronie disease)

Deep (musculoaponeurotic)

- Extraabdominal fibromatosis
- Abdominal fibromatosis
  - Abdominal wall fibromatosis
  - Intraabdominal fibromatosis
    - Mesenteric fibromatosis
    - Retroperitoneal fibromatosis
    - Pelvic fibromatosis
- Fibromatosis associated with Gardner syndrome
- Infantile myofibromatosis
- Fibromatosis colli

❖ Superficial Fibromatosis

i) Palmar Fibromatosis

- Palmar fibromatosis (Dupuytren disease) is the most common type of fibromatosis.
- Age: Old age > 65y
- Sex: M >>> F

Clinical presentation:

- Subcutaneous nodules and fibrous cords on the palmar surface at the level of the distal crease of the hand
- They attach to and cause traction on the adjacent flexor tendons, resulting in flexion contractures of the digits.
- The fourth and fifth rays are most commonly affected
- followed by the second and third rays

Imaging Findings:

T1: Low signal

T2:

- Low signal (due to hypocellularity & predominant dense collagen)
- Intermediate - High signal (more cellular & relatively less collagen and thus more likely to locally recur)

a.

ii) Plantar fibromatosis (Ledderhose disease)

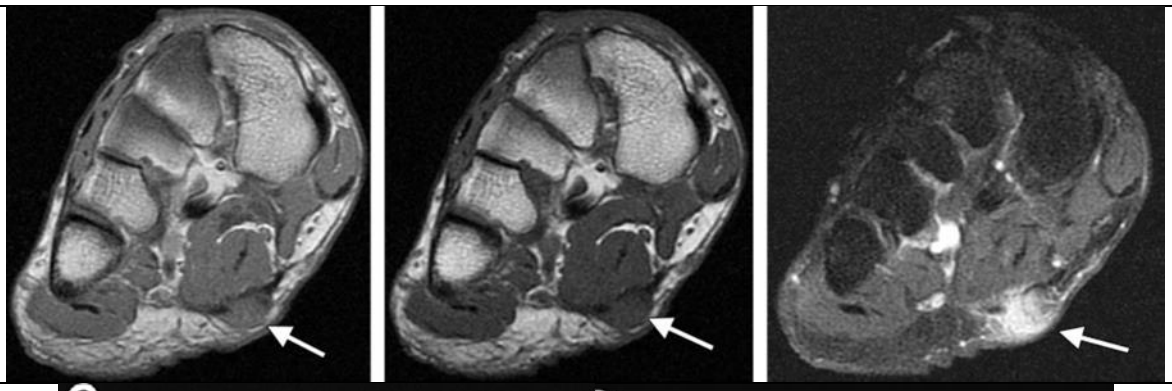
- Develop most commonly in the medial aspect of the plantar aponeurosis.
- Age: 30 and 50 years,
- Bilateral in 20%– 50% of cases.
- Concomitant palmar fibromatosis in 10%–65% of patients

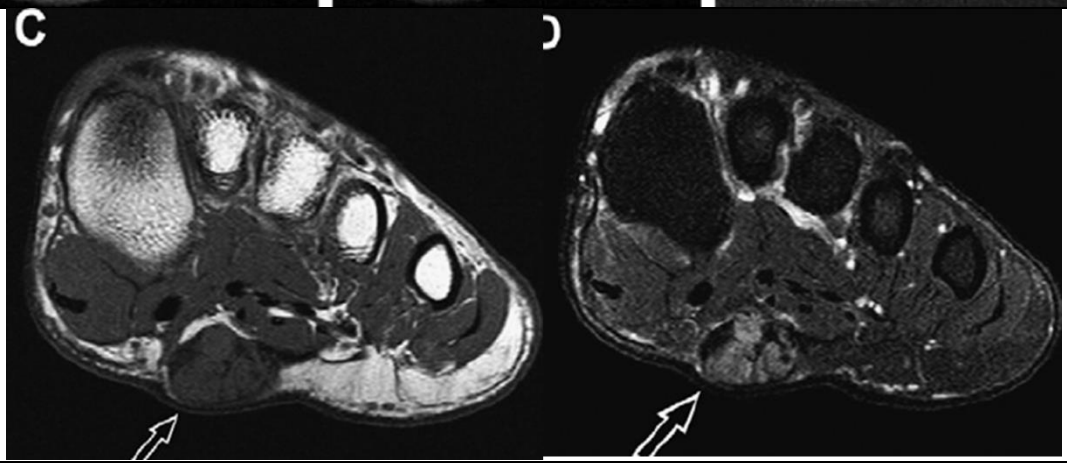
Clinical Presentation:

- They usually manifest as one or multiple firm, fixed, subcutaneous nodules, which can extend to involve the skin or invade the deep structures of the foot

Imaging Findings:

- Ill defined, infiltrative mass occurring in the deep aponeurosis adjacent to the plantar muscles in the medial aspect of the foot
- T1: Low signal
- T2:
    - Low signal (due to hypocellularity & predominant dense collagen)
    - Intermediate - High signal (more cellular & relatively less collagen and thus more likely to locally recur)
- +C: variable enhancement.





iii) Penile Fibromatosis = Peyronie Disease

- One cause of erectile dysfunction that is well depicted at MRI.
- Fibrous plaques at the tunica albuginea.

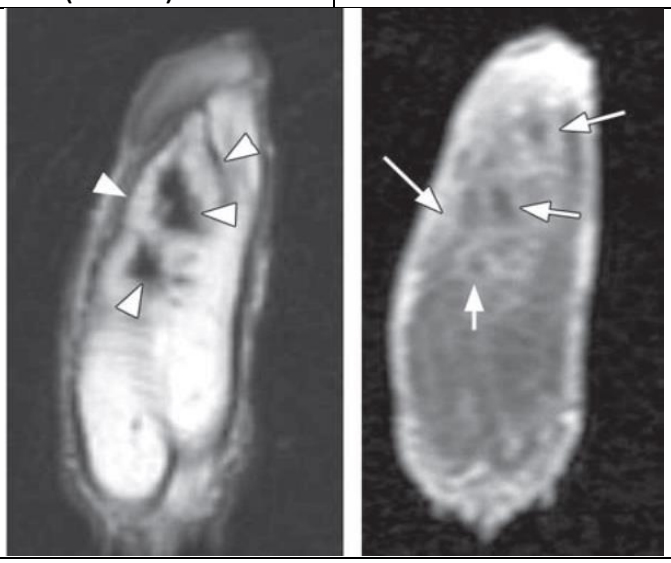
MRI findings:

- Low SI areas of thickening in the tunica albuginea with both T1 and T2.
- Gadolinium-based contrast material to show active inflammation.

2 Clinical Phases:

- An acute phase (12–18 months):
  - Pain during erection.
  - Sometimes flaccidity during intercourse
- A chronic phase:
  - Pain is less conspicuous
  - Penile deformity is dominant—typically a dorsal angulation but sometimes ventral or lateral
  - Often associated with shortening.

Coronal T2	Coronal T1+C
Peripheral plaque in the distal corpus cavernosum (arrow)	mild peripheral enhancement



iv) Juvenile Aponeurotic Fibroma

- Juvenile aponeurotic fibroma is a rare, locally aggressive fibroblastic lesion
- Location: palms of the hands and soles of the feet
- Age: ***young children***
- Sex: M > F
- frequently calcify and is also referred to as ***calcified aponeurotic fibroma***

Imaging Findings:

- Nonspecific soft-tissue mass
- Fine stippled calcifications
- occasional scalloping of the adjacent bone
- Biopsy is important in evaluation of these lesions and differentiation from synovial sarcoma.

v) Infantile Digital Fibromatosis

- This lesion has also been referred to as ***Reye tumor***, ***infantile digital fibroma***, and ***infantile digital myofibroblastoma***
- Infantile digital fibromatosis occurs in the fingers and toes of infants.

Location & Distribution:

- **Fingers (60% of cases)**
- **Toes (40% of cases)**
- Dorsal and lateral aspect of the distal or middle phalanx
- No bone involvement.

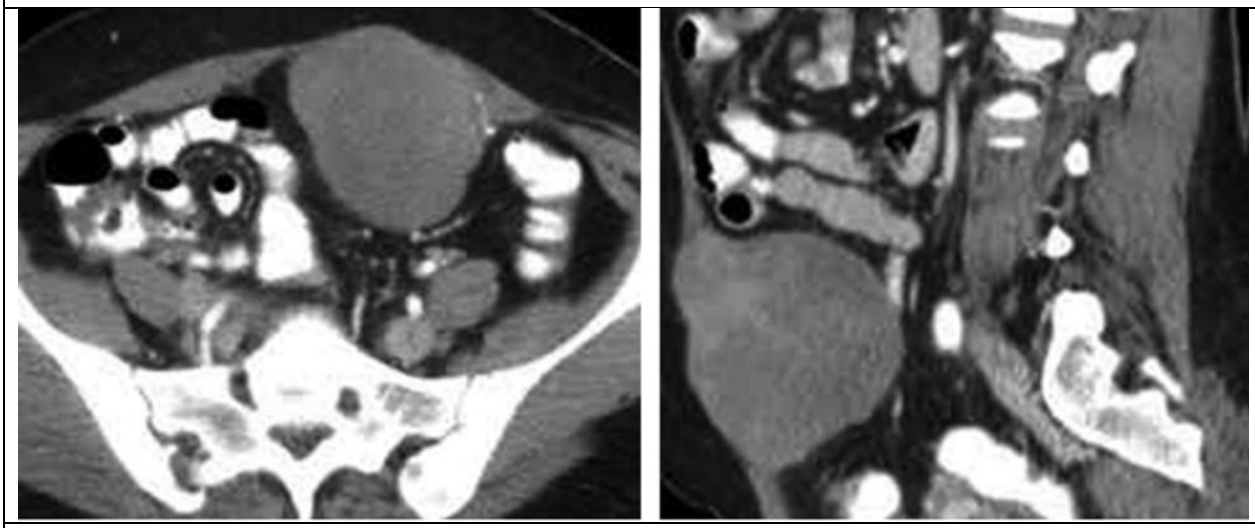
❖Deep Fibromatoses

i) Abdominal Fibromatosis

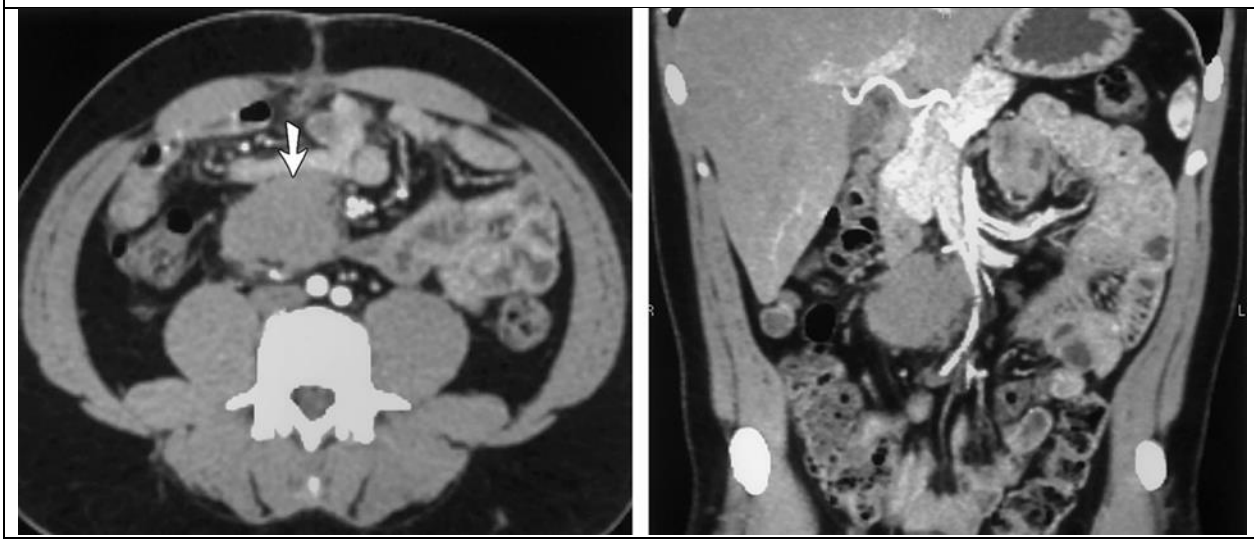
Imaging Findings:

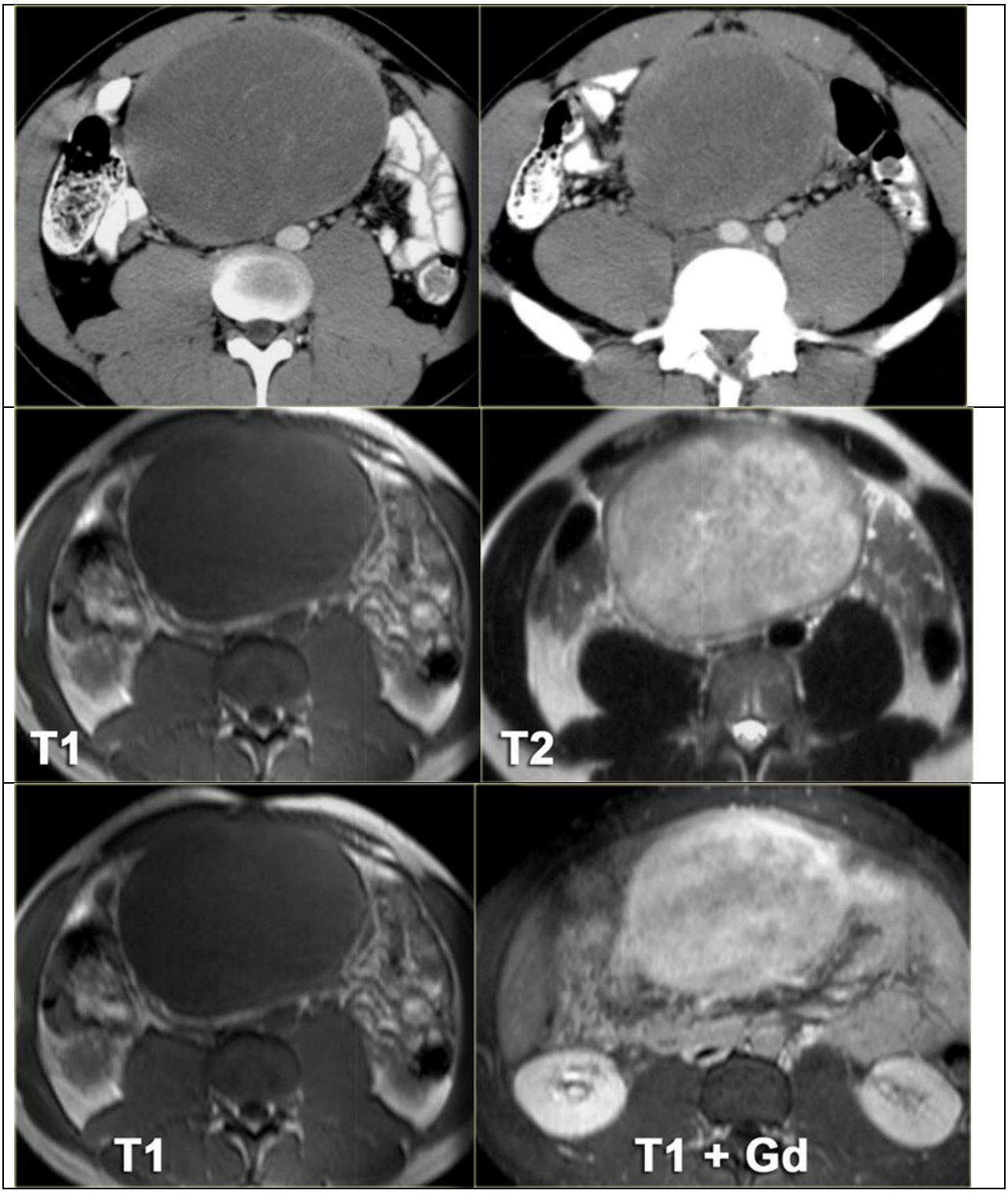
- Well defined Soft-tissue masses
- A “whorled appearance” of fibrosis growing into the mesenteric fat
- CT: Isoattenuating relative to muscle
- T1: low signal intensity
- T2: low signal intensity
- C+: may show homogeneous, inhomogeneous, or no significant enhancement

Abdominal Wall Desmoid Tumor



Mesenteric Desmoid Tumor




T1
T2
T1
T1 + Gd

ii) Extra-abdominal Desmoid Tumor

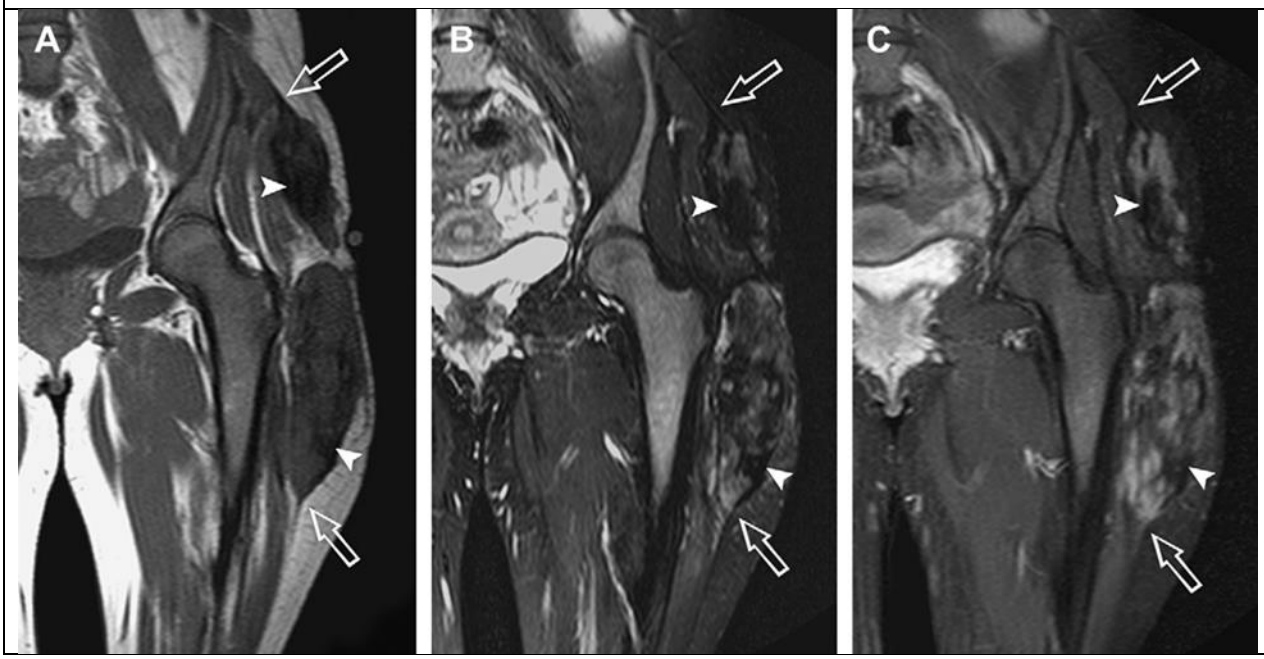
- Frequent cause of a soft-tissue mass in adults
- Age: Young adults (25 - 35 years)

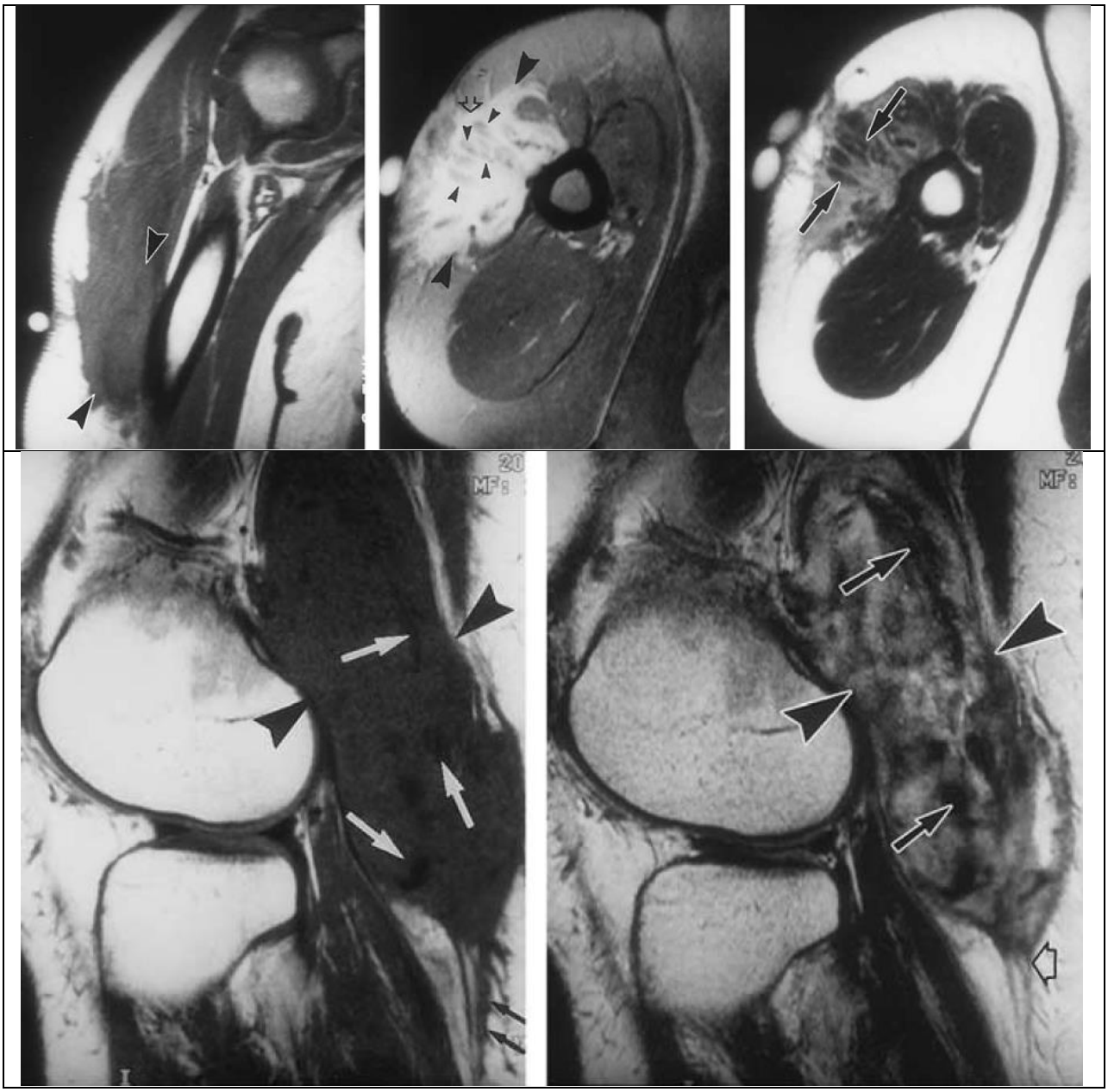
Location & Distribution:

- Extremities account for approximately 70% of cases.
    - Shoulder (20%), chest wall and back (15%)
    - Thigh (12%), neck (10%), and knee (7%)

Imaging Findings:

- An ill-defined infiltrative lesion
- Intermuscular lesion + muscle invasion + linear extension along fascial planes
- Heterogeneous signal intensity pattern likely corresponds to the varying proportions of cellular tissue, myxoid tissue (high water content and high signal intensity on T2), and collagen (low signal intensity with all pulse sequences)
- T1: Low signal
- T2:
    - Low signal (due to hypocellularity & predominant dense collagen)
    - Intermediate -High signal (more cellular & relatively less collagen and thus more likely to locally recur)
- +C: variable enhancement.



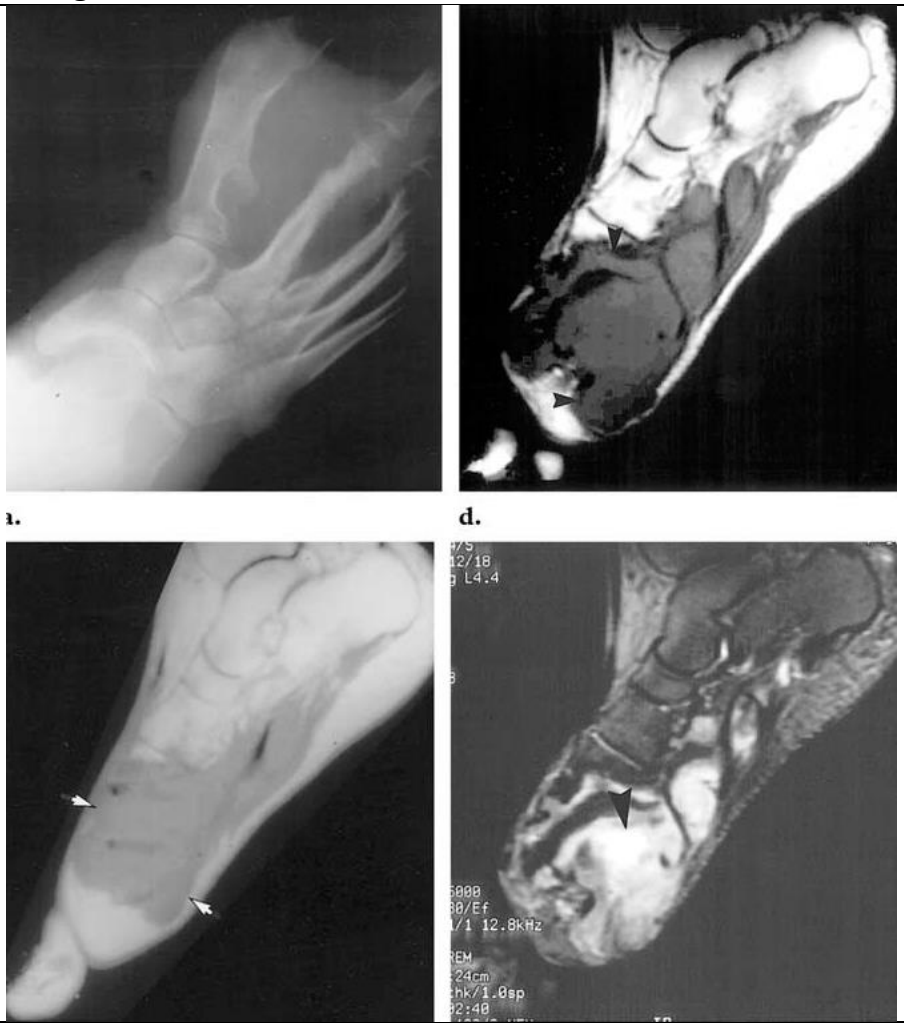


iii) Aggressive Infantile Fibromatosis

- Aggressive infantile fibromatosis is the childhood equivalent of deep extra-abdominal fibromatosis
- Age: first 2 years of life

Location & Distribution:

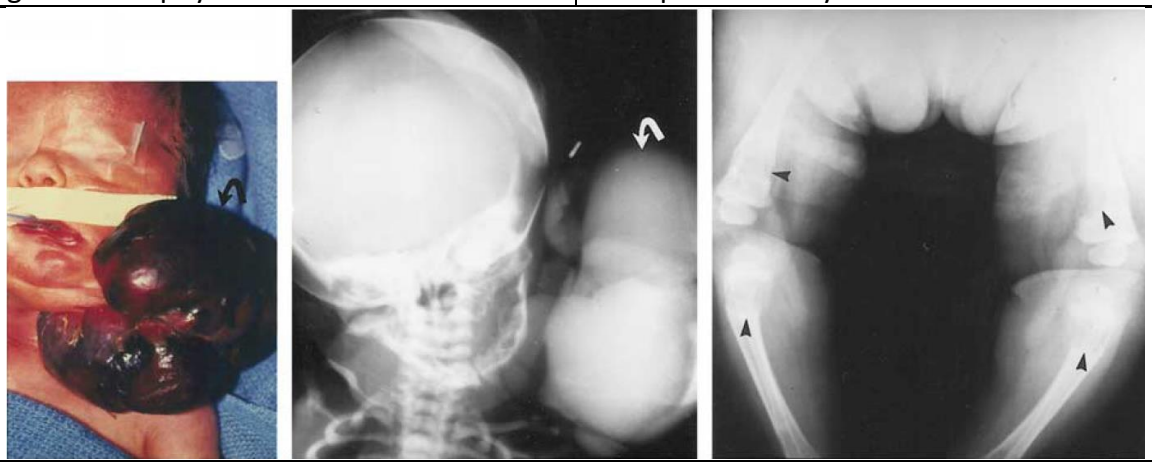
- The most common location is the head and neck:
  - Tongue, mandible, and mastoid process.
- Shoulder, thigh, and foot



iv) Infantile Myofibromatosis

- is a solitary or multicentric proliferation of fibrous tissues and represents a distinct subtype of the fibromatoses
- Age < 2 years.
- Multicentric disease often affects multiple organ systems including skeletal muscle, bone, soft tissue, skin, and viscera such as the lung and liver

Large neck exophytic lesion	Multiple skeletal lytic lesions



v) Fibromatosis Colli

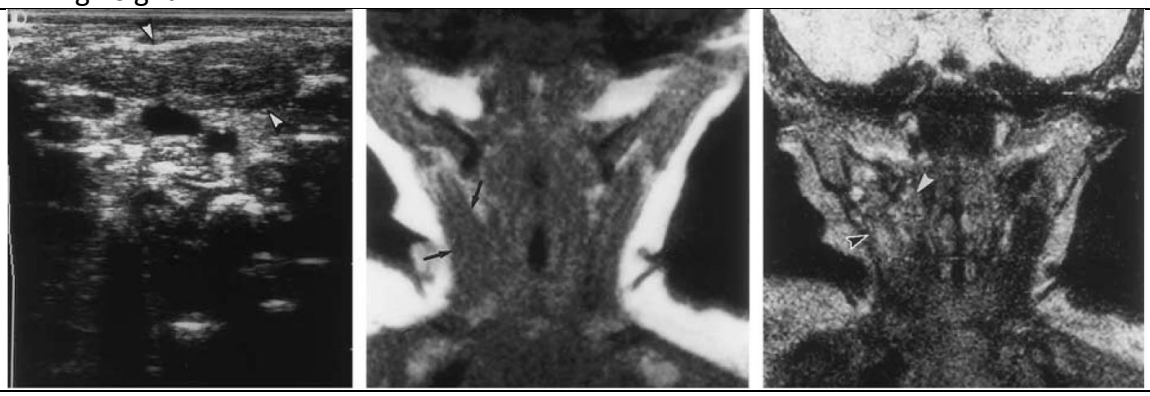
- Rare form of infantile fibromatosis that occurs solely in the sternocleidomastoid muscle.

Clinical Presentation:

- No abnormality at birth
- Manifest between the 2nd and 4th weeks of life
- Firm soft-tissue mass in the lower one third of the sternocleidomastoid muscle
- Unilateral

Imaging Findings:

- Mild enlargement of the lower one-third of the sternocleidomastoid muscle
- Diffuse abnormal signal intensity
- US: Hypoechoic
- T2: High signal



7) Solitary Fibrous Tumor (SFT) = Hemangiopericytoma (HPM)

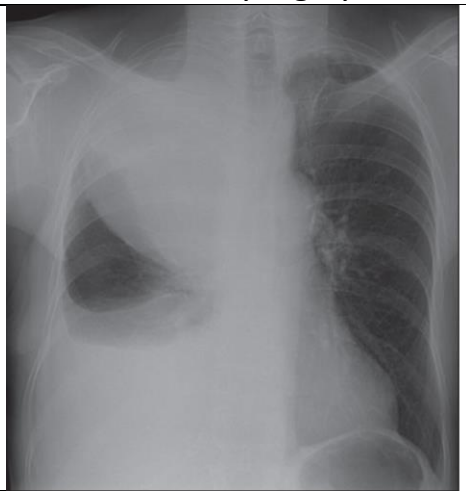
- Rare soft-tissue tumors
- Age: Adults in middle age

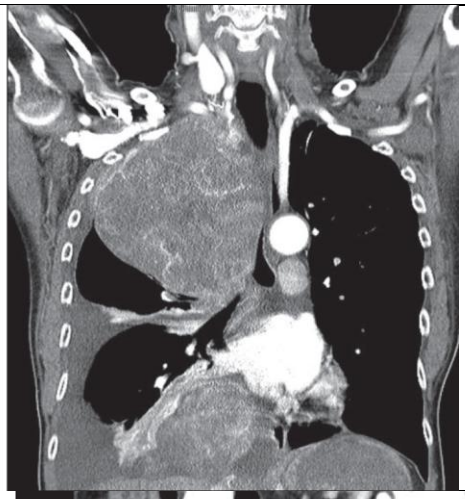
Location & Distribution:

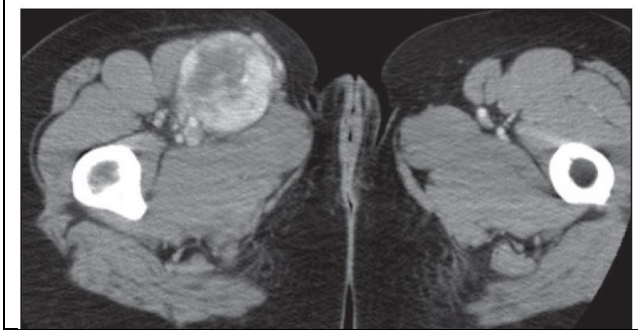
- First described as originating from the pleura
- Most commonly in the thoracic cavity
- The most commonly reported extra-thoracic locations are:
  - Retroperitoneum
  - Deep soft tissues of the proximal extremities,
  - Abdominal cavity
  - Head and neck

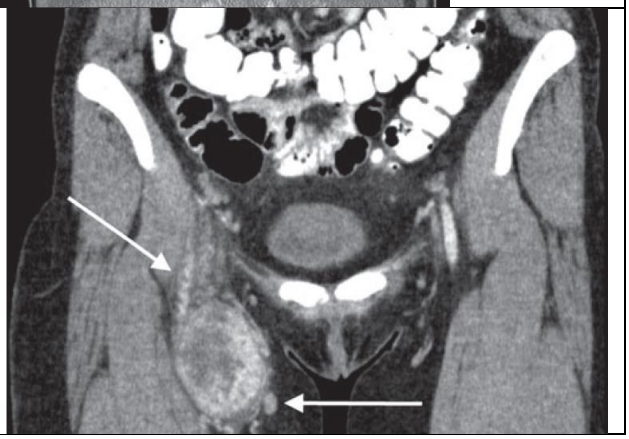
Imaging Findings:

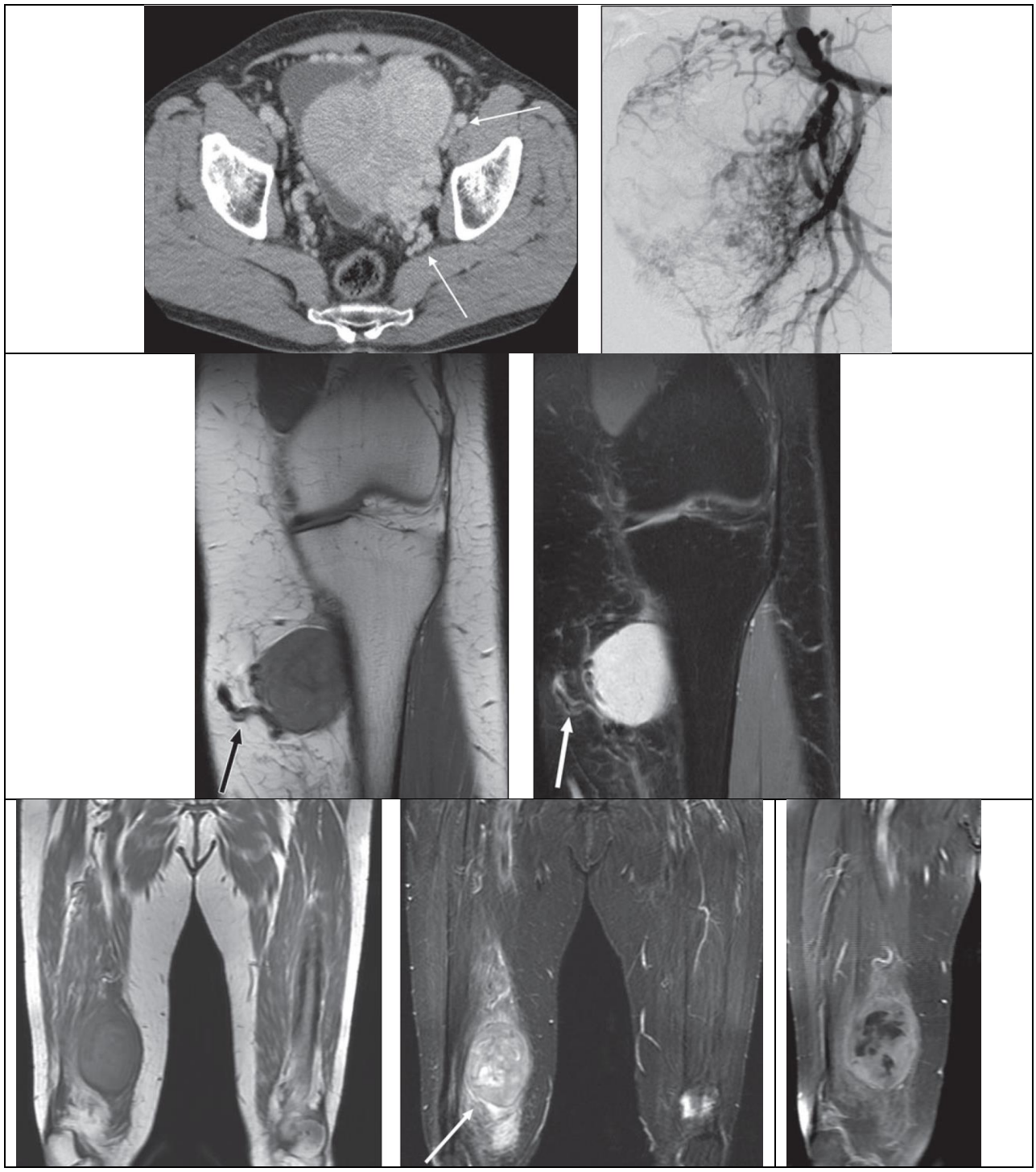
- Well-defined, lobulated lesions
- Non-specific imaging Findings.
- Large collateral feeding vessels
- Tumors were usually highly vascular and had avid contrast enhancement





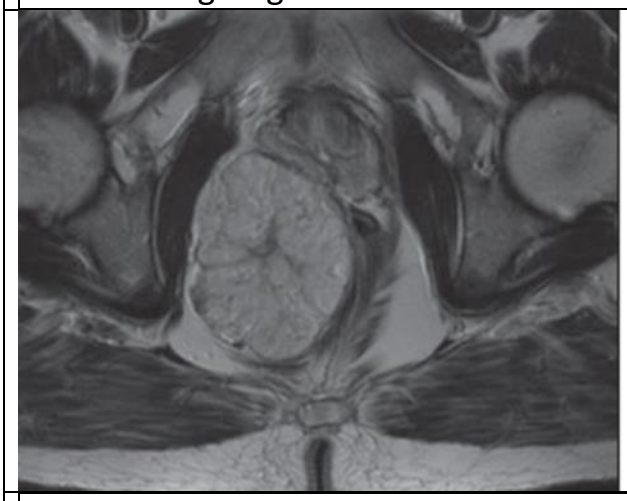
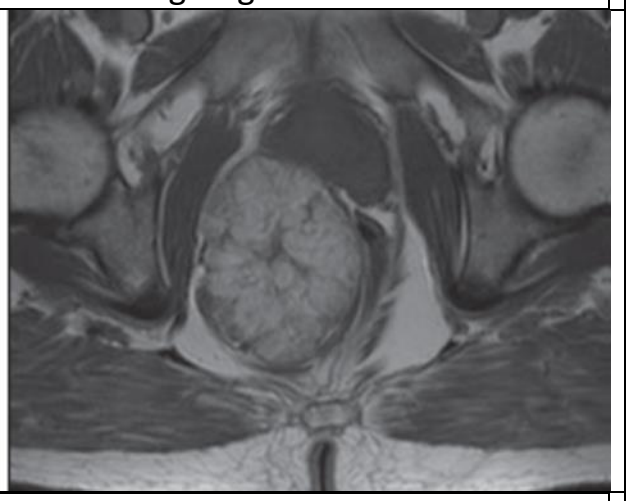
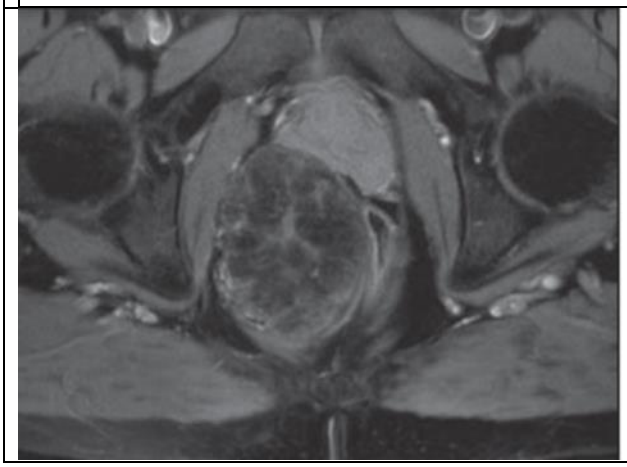
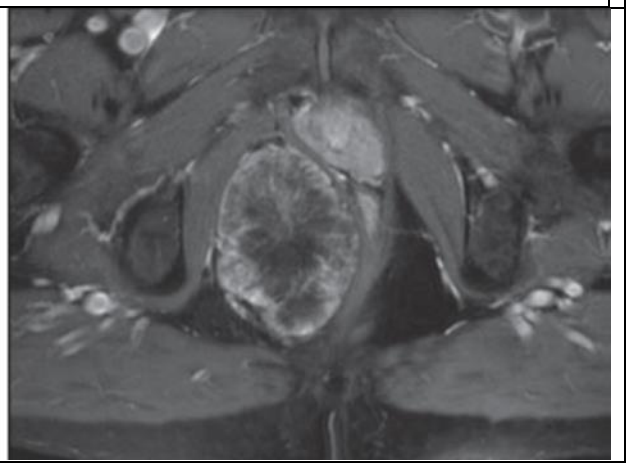


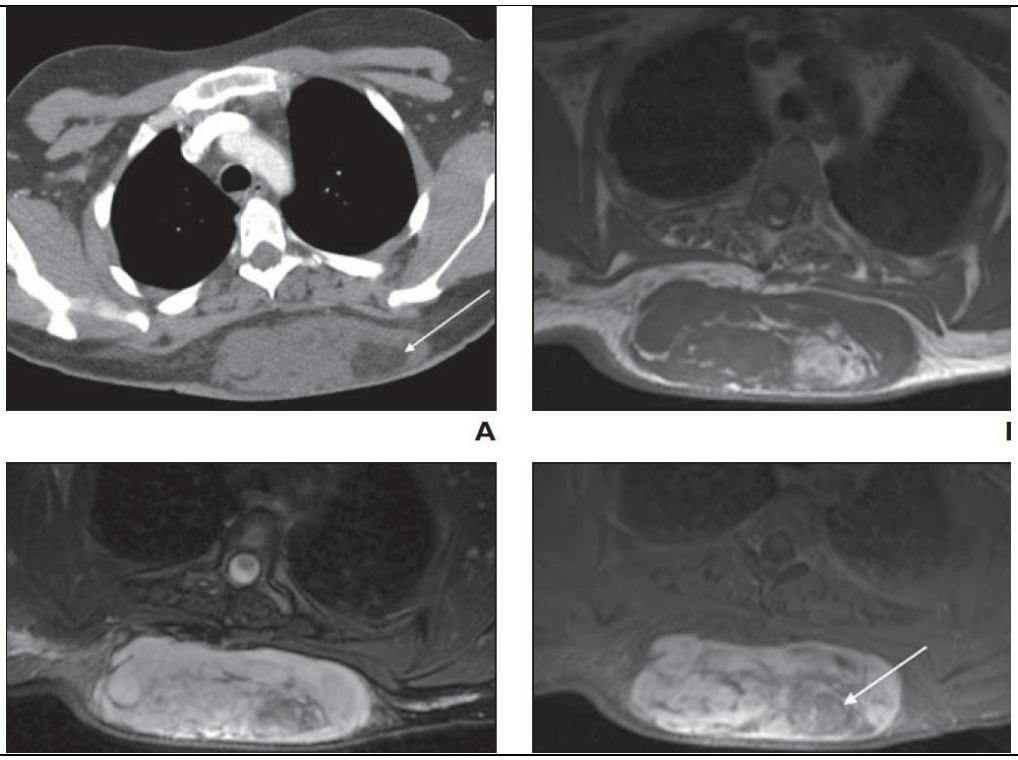




Lipomatous Hemangiopericytoma

is subtype of SFT that contains fat.

Axial T2: high signal	Axial T1: High signal
	
Axial T1 FS	Axial T1 FS +C
	

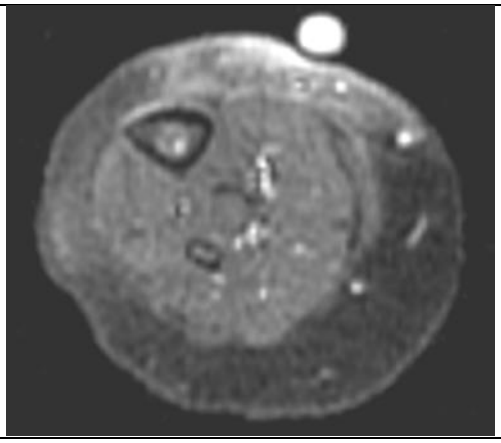


8) Dermatofibrosarcoma Protuberans

- Dermatofibrosarcoma protuberans is a rare soft-tissue sarcoma of intermediate malignancy.
- Age: more commonly seen in middle-age adults
- Location: It is most commonly found on the trunk or proximal extremities but can occur anywhere.
- The tumor originates in the dermis but spreads locally into the deeper tissues, such as the subcutaneous tissues, fascia, muscles, and bones.

Imaging Findings:

- A well-defined mass, generally confined to the subcutaneous tissues.
- T1: iso- to hypointense to muscle
- T2: hyperintense
- Uniform or patchy enhancement with a gadolinium contrast agent



9) Adult Fibrosarcoma

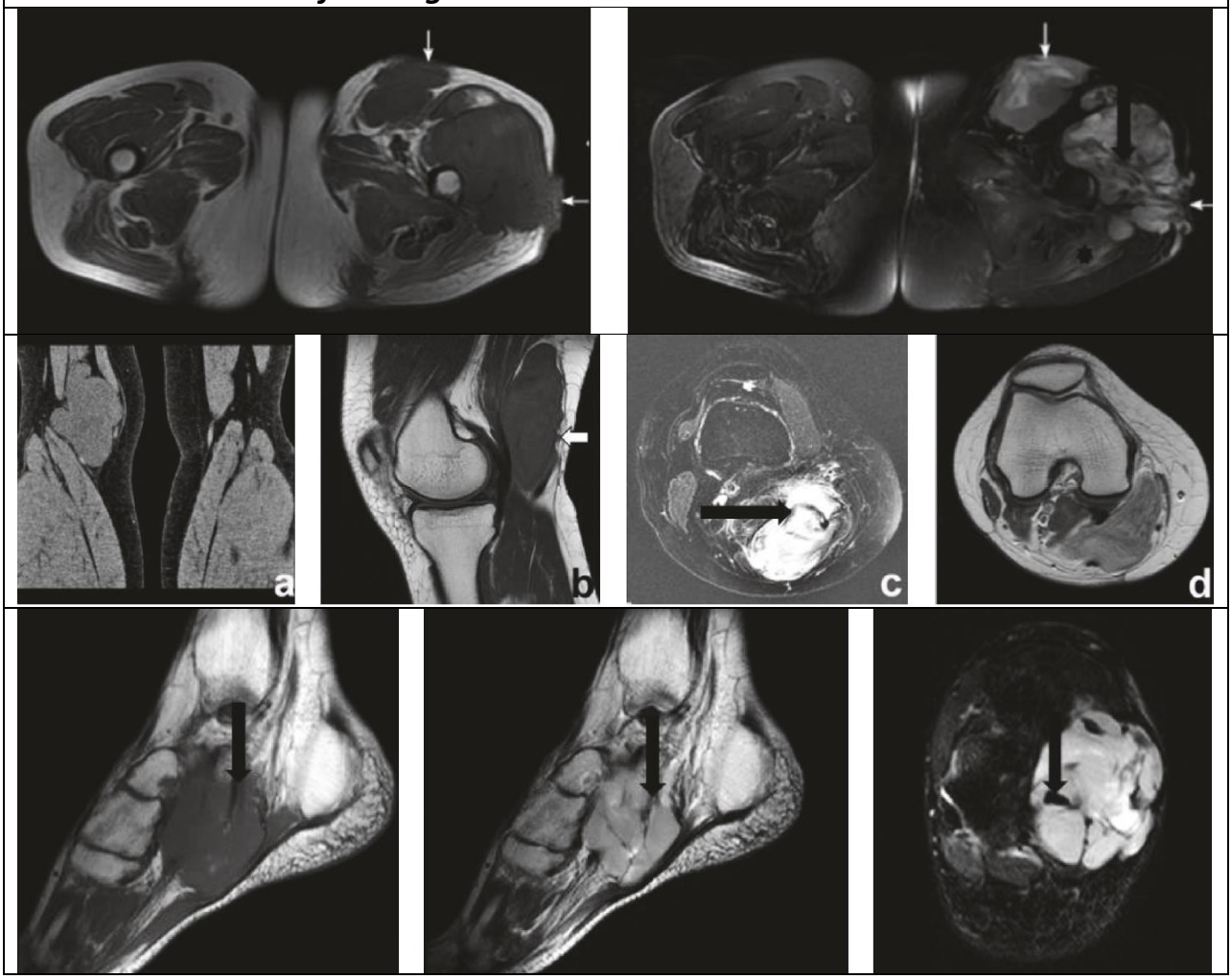
- Adult fibrosarcoma is a rare neoplasm composed of malignant spindle-shaped fibroblasts with variable collagen production.

Location & Distibution:

- Deep soft tissues of the trunk and the upper and lower extremities

Imaging Findings:

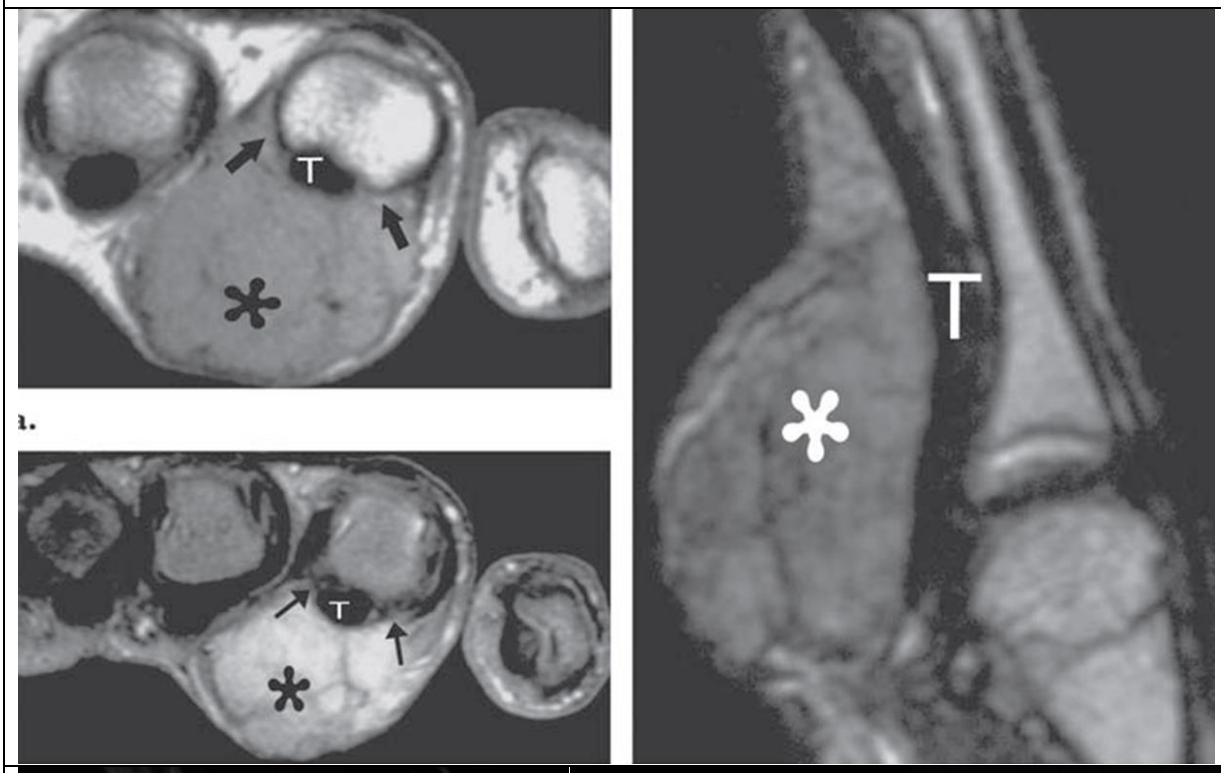
- T1: low signal
- T2: heterogeneous signal
- +C: Heterogeneous enhancement.
- ***Band-like areas of low signal on both T1WI and T2WI***



B- Fibroblastic/Myofibroblastic Tumors

Giant Cell Tumor Of The Tendon Sheath (GCTS)

- It most commonly affects joints in the hand and occurs on the volar (palmar) surface near the distal interphalangeal joint.
- 2nd most common mass of the hand (1st = ganglion).
- A well-circumscribed, soft-tissue mass adjacent to the involved tendon.
- Small extensions about the tendon margin are seen in most cases and suggest a tenosynovial origin. These extensions may entirely encase the tendon.
- T1 & T2: Low to intermediate signal intensity
- +C: contrast enhancement



IV- Soft Tissue Calcification / Ossification

A- Dystrophic Calcification:

- Soft tissue calcification in injured or devitalized tissues in presence of normal serum calcium and phosphorus

- Vascular
  - Venous insufficiency
- Infection
  - Granulomatous infection
- Parasitic infestation
  - Cysticercosis
  - Dracunculiasis
  - Armillifer armillatus
- Neoplasm
  - Primary bone-forming tumours: osteosarcoma
  - Other sarcomas: specially synovial sarcoma
  - Osteoma
  - Tumour necrosis
- Drugs
  - Vitamin D
  - Milk-alkali syndrome
- Autoimmune
  - Dermatomyositis
  - Scleroderma and crest syndrome
- Trauma
  - Heterotopic ossification
  - Injection granuloma

B- Calcinosis

- Calcium deposition in skin and subcutaneous tissues in the presence of normal calcium metabolism

- Calcinosis circumscripta
- Tumoral calcinosis
- Idiopathic calcinosis universalis

C- Metastatic Calcification

- Deposition of calcium salts in previously normal tissue resulting due to abnormal calcium metabolism.
- Most common in chronic renal disease on hemodialysis.

- Hyperparathyroidism
- Renal osteodystrophy
- Sarcoidosis
- Massive osteolysis

❖ Chondro-Osseous Tumors

Benign
- Soft tissue chondroma

Malignant
- Extraskeletal mesenchymal chondrosarcoma
- Extraskeletal osteosarcoma

❖ Tumors with Secondary Calcifications / Ossifications

- Lipoma
- Synovial sarcoma
- Hemangioma

❖ Chondrocalcinosis

- Calcification of cartilage
  - Gout – calcium urate crystals
  - Pseudogout – calcium pyrophosphate
  - CPPD – calcium pyrophosphate
  - Ochronosis – homogentisic acid oxidase
  - Hyperparathyroidism (2° more common)
  - Diabetes

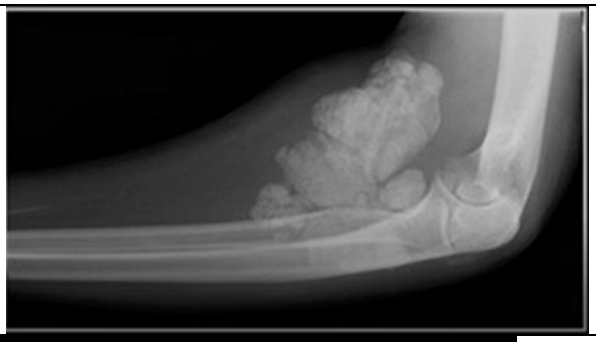
❖Calcinosis

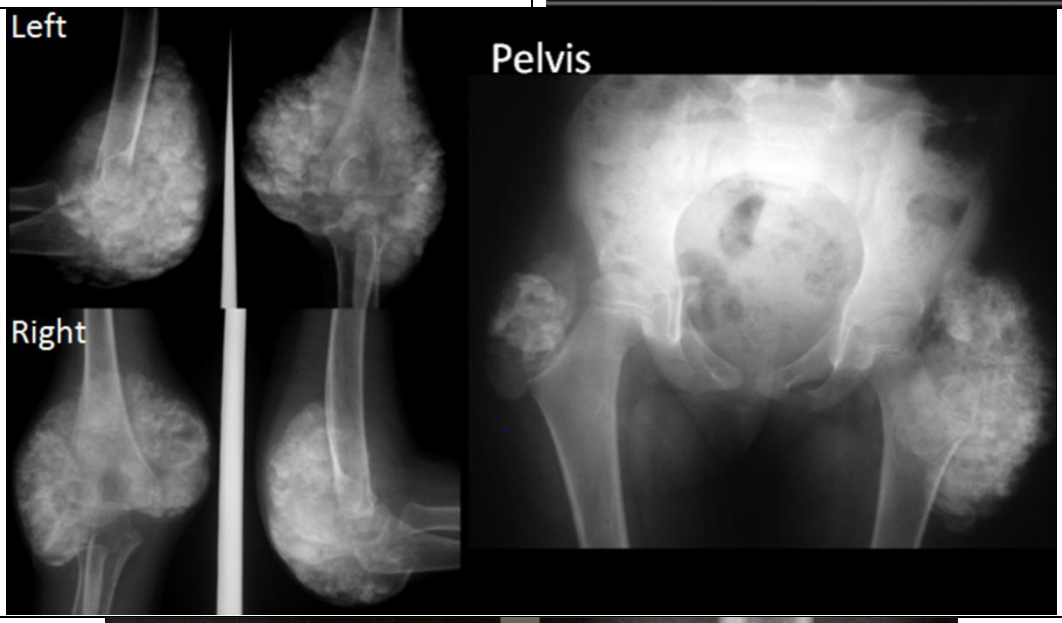
i. Tumoral Calcinosis

- is rare familial condition characterized by painless, **peri-articular masses**.

Imaging Findings:

- Amorphous, cystic, and multilobulated calcification located in a periarticular distribution.
- No erosion or osseous destruction by adjacent soft-tissue masses.





ii. Calcinosis Circumscripta

- Calcium deposition in the subcutaneous tissues, muscles and fascia
- Association with Raynaud syndrome, **scleroderma** or dermatomyositis in up to 40% of cases.
- Fine clustered calcifications are seen, usually around the **finger and toe tips**

iii. Calcinosis Universalis

- <20 years of age, and is more common in women.
- Long bands or sheets of symmetrical subcutaneous calcification.
- Palpable calcific plaques in subcutaneous or deeper tissue
- Fatigue, muscle pain, and stiffness
- Associated with scleroderma, **dermatomyositis**, polymyositis, and SLE

❖Vascular Calcifications

i) Mönckeberg Arteriosclerosis:

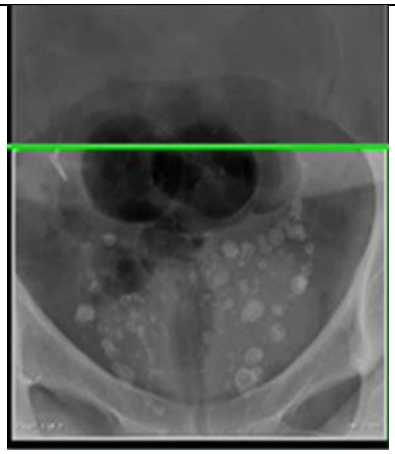
- Calcific deposits within the media of medium and small muscular arteries
- Do not cause luminal narrowing
- Rail road track calcifications
- Common in diabetic
- Vascular calcification in the breast on mammography

ii) Intimal Atherosclerosis:

Discontinuous plaque like calcifications.

iii) Venous Pheleboli:

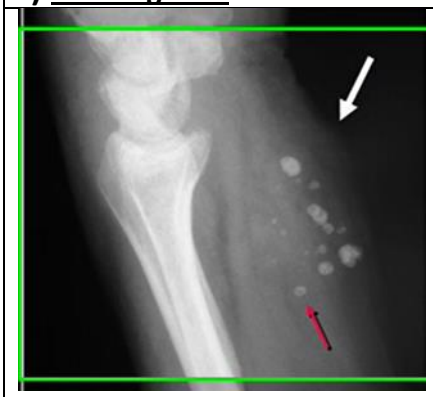
Rounded calcification with Central lucency



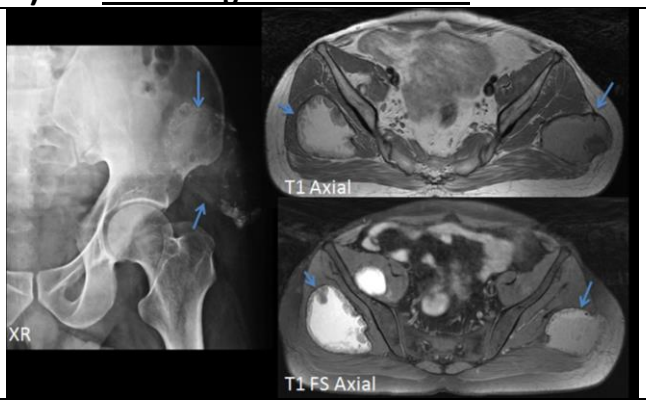
iv) Venous Calcification secondary to chronic venous disease:

Subcutaneous sheet likely calcifications in calf

v) Hemangioma



vi) Calcified gluteal Hematoma



❖Heterotopic Ossification = Myositis Ossificans:

i) Fibrodysplasia Ossificans Progressiva

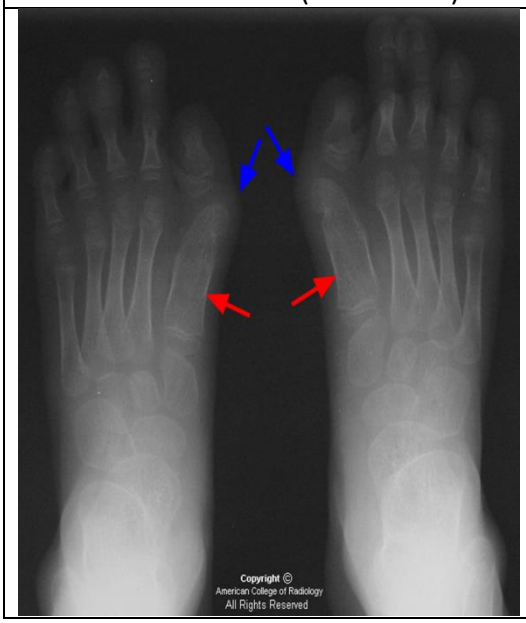
- Rare, inherited disorder characterised by progressive fibrosis and ossification of muscles, tendons, fasciae, aponeuroses, and ligaments of multiple sites.
- It is disabling and ultimately fatal.

- Starts in neck
- Proceed slowly caudally
- Back then whole body

- Associated with microdactaly (great toe, thumb, middle phalynx of 5th finger)

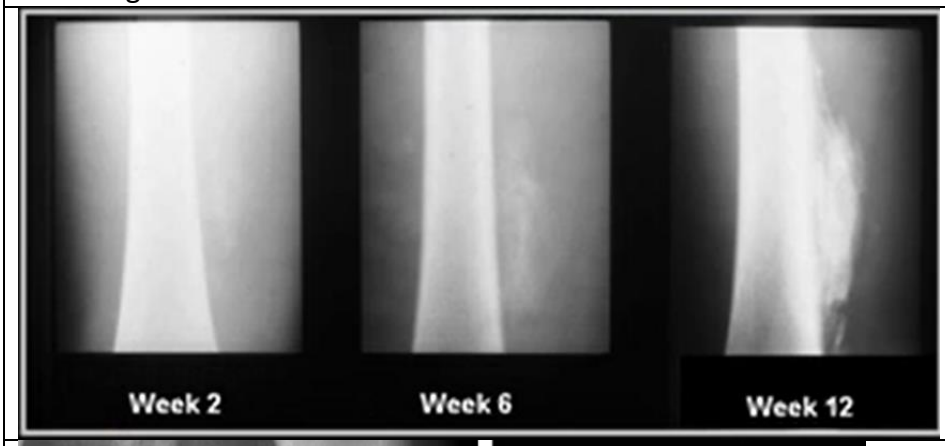
Bilareal hallux valgus deformity of the great toes (blue arrows) with microdactyly and short 1st metatarsals (red arrows).

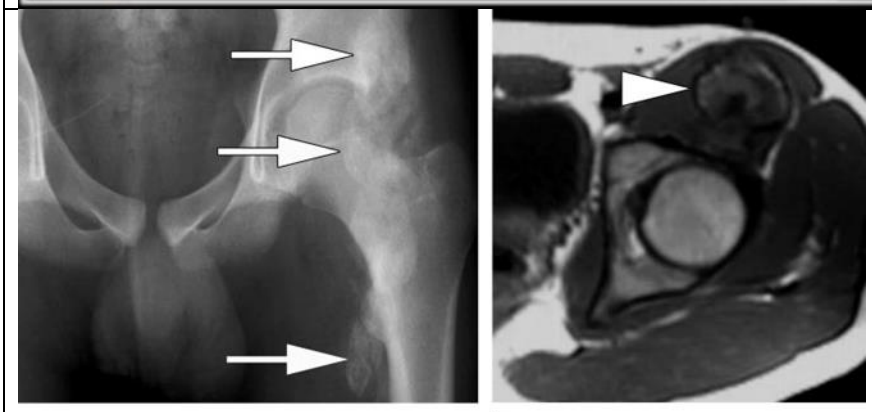
Bilateral short first metacarpals of the hands (arrows).

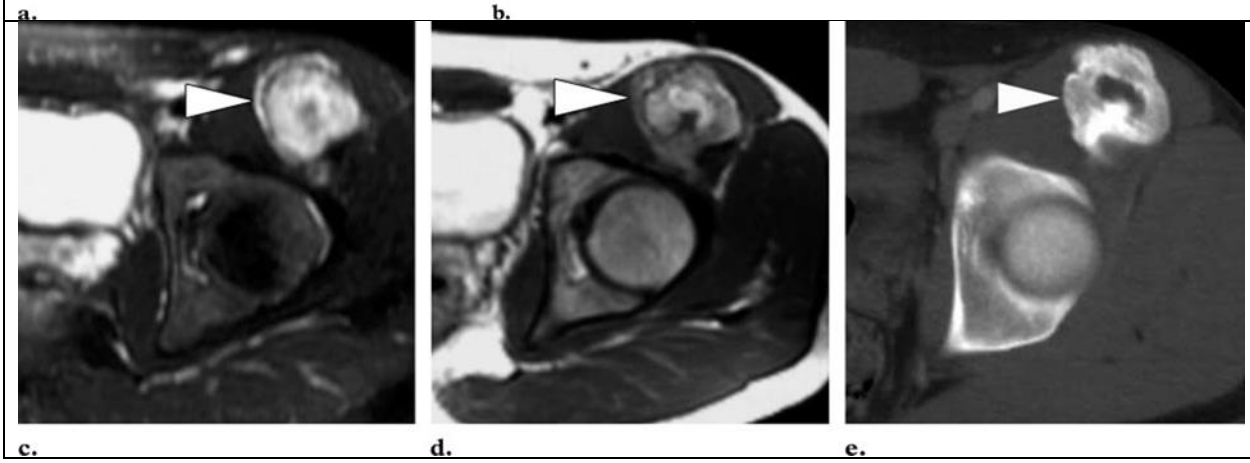


ii) Heterotopic Ossification 2ry to Trauma:

- Localized to site of injury
- Calcification is rarely seen on radiographs in the first few weeks but can become apparent 3–8 weeks after onset, starting peripherally and progressing centrally in a zonal pattern
- Mature to bone
- Along axis of muscle.



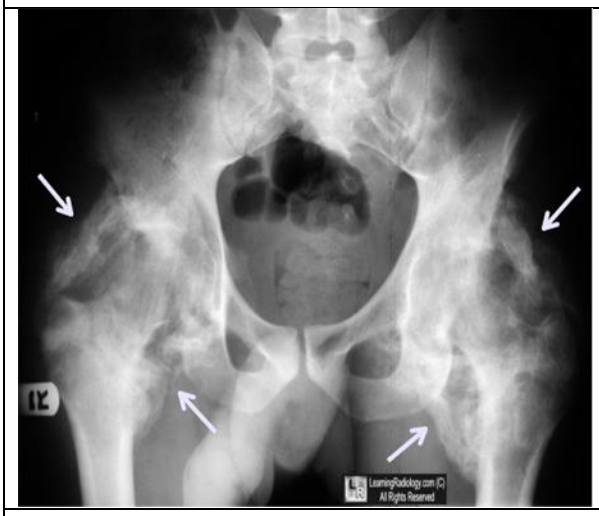




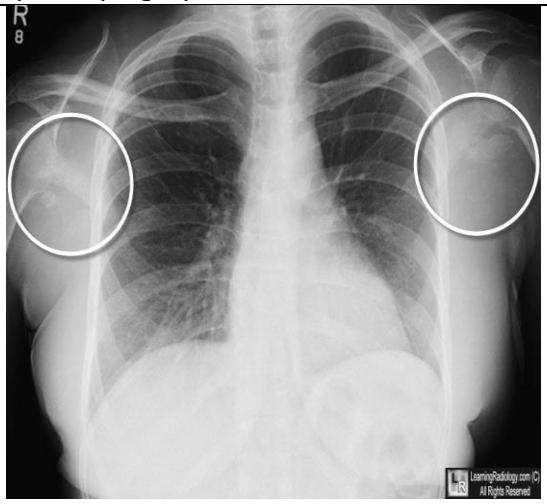
iii) Neurogenic Heterotopic Ossification

- Neurogenic HO is a known but uncommon complication that occurs after a cerebral or spinal insult.
- Around large joints: Hips, knees, shoulders

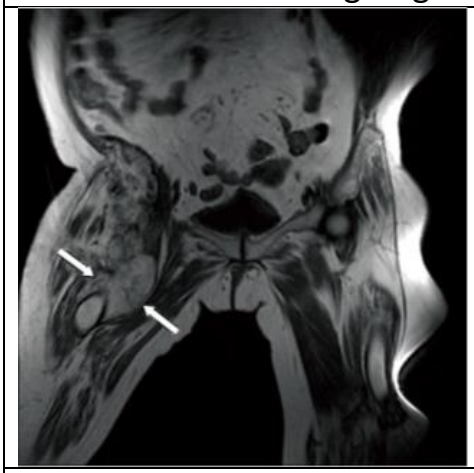
Heterotopic ossification surrounding both hip joints in young patient with traumatic brain injury

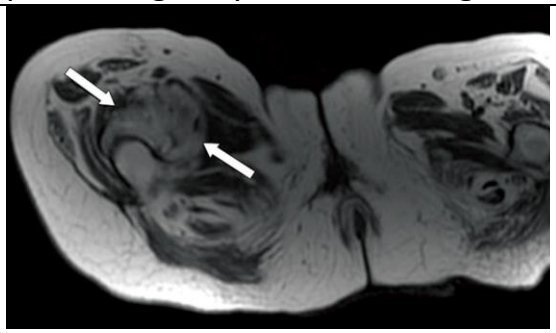


Heterotopic ossification in both axillae in a quadreplegic patient

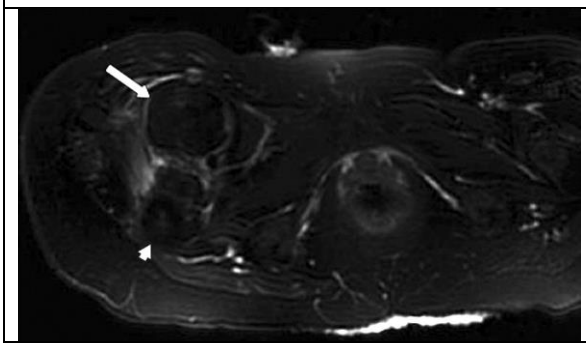


Axial & Coronal T1: high signal centrally representing fatty marrow change

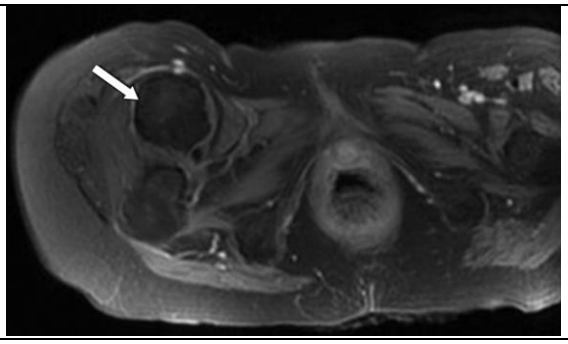




Axial T2 FS



Axial T1 +C FS



V- Non-Specific Imaging Findings

❖Rhabdomyosarcoma

- is the most common pediatric soft-tissue sarcoma
- 3–5% of all malignancies in childhood
- 3rd most common extracranial tumor after wilms' tumor and neuroblastoma.
- Age: Children (70-80% <10 y)
- Sex: M > F

Location & Distribution:

- Head and neck: 50%
  - Parameningeal (PM) 50%
  - Orbit: 20%
  - Oropharynx/nasopharynx, palate: 15%
  - Sinuses, mastoid, middle ear: 15%
- Genito-urinary: ~25%
  - Paratesticular: ~20%
  - Vaginal
  - Bladder/Prostate: ~5%
- Extremities: ~15%
- Trunk and thorax: 7%
- Gastrointestinal tract: 1%

Histological Subtypes => ③:

i. Embryonal rhabdomyosarcoma (75%)
   - Spindle cell rhabdomyosarcoma: 50-66%
   - Botryoid rhabdomyosarcoma: 5-10% (best prognosis)
   - Anaplastic rhabdomyosarcoma

ii. Alveolar rhabdomyosarcoma: 20%

iii. Pleomorphic rhabdomyosarcoma: 5%

Radiological Features:

- Aggressive ill defined soft tissue lesion
- T1: Low signal
- T2: Heterogeneous high signal
- +C: heterogeneously enhancement
- Bone destruction
- Invasion of adjacent fascial planes/spaces

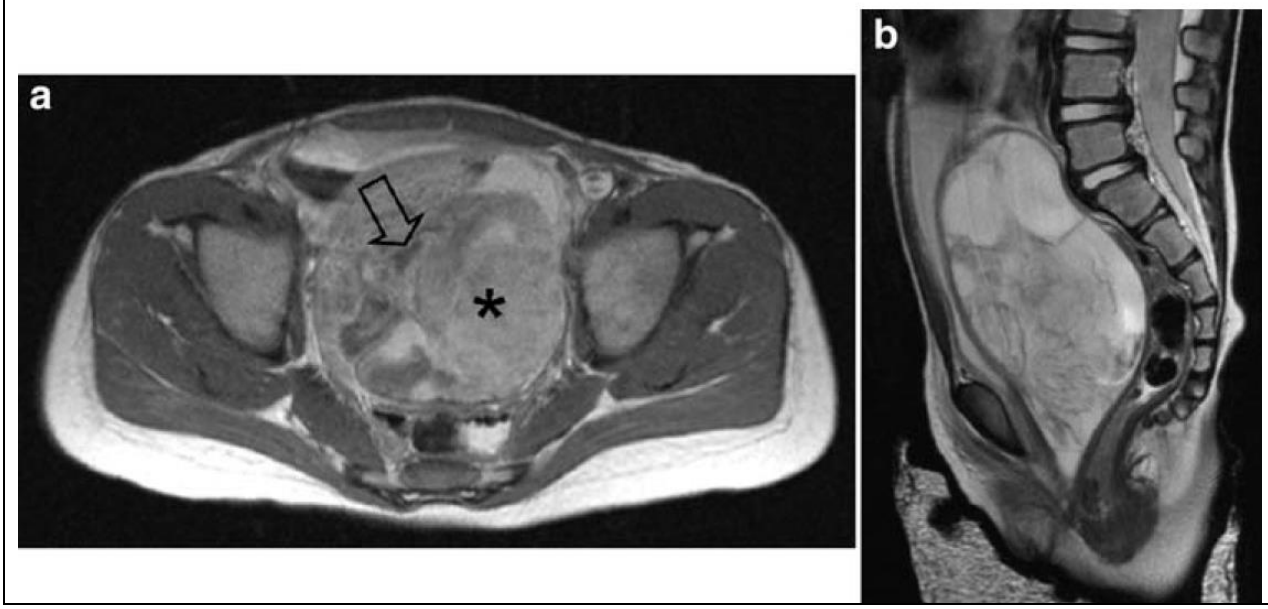
Table 3 IRSG classification

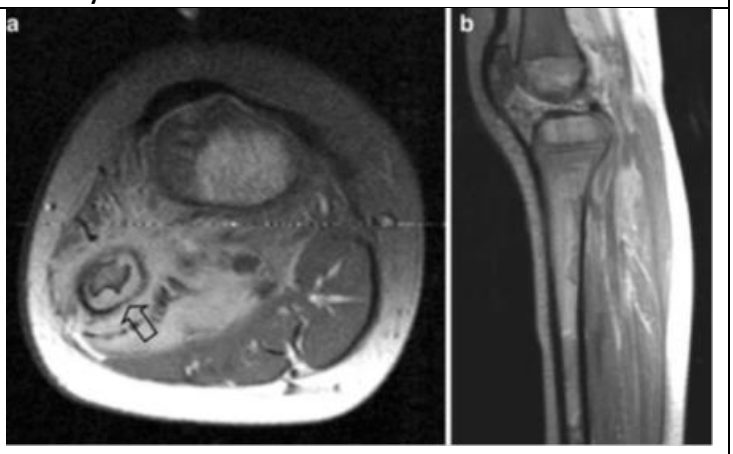
Stage	Characteristics	
I	Localized disease completely resected (regional nodes not involved)	A: Tumour confined to muscle or organ of origin B: Tumour infiltrating outside organ of (muscle of) origin
II	Localized or regional disease with total resection of gross tumour	A: Primary tumour grossly resected, with microscopic residual disease (negative findings in local nodes) B: Primary tumour and positive nodes completely resected C: Primary tumour and positive nodes resected, with evidence of microscopic residual disease
III	Incomplete resection of tumour or biopsy, with gross residual disease	
IV	Distant metastatic disease present at diagnosis	

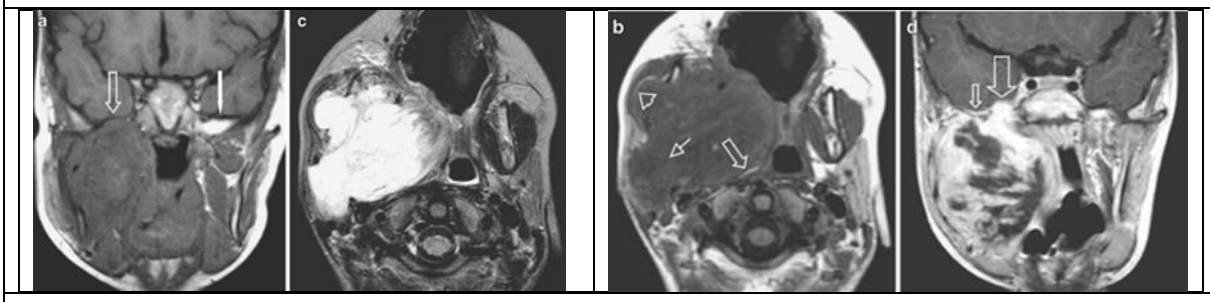
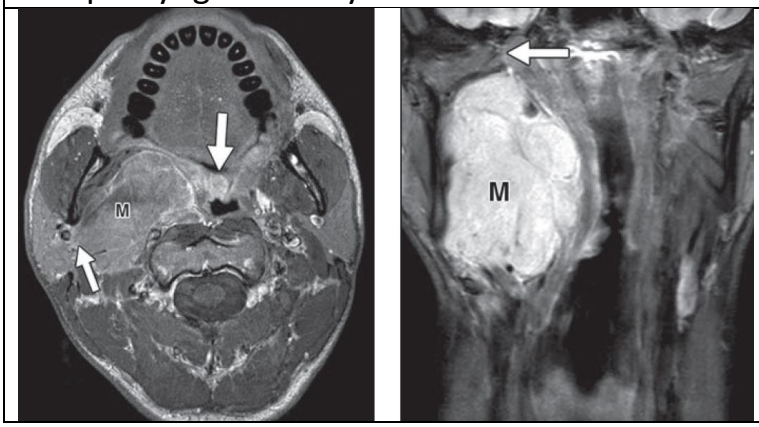
Table 4 Regional node stations by primary tumour site. Disease with involvement of other lymph nodes than those specified in the table should be classified as stage IV

Anatomical site		Node station
Extremity	Lower extremity	Inguinal, femoral, popliteal nodes (rare)
	Upper extremity	Axillary, brachial, epitrochlear, and infraclavicular nodes
Genitourinary	Bladder, prostate, cervix, uterus, paratesticular	Pelvic, retroperitoneal nodes at renal artery level or below
	Vagina	Retroperitoneal, pelvic nodes at or below common iliac inguinal nodes
	Vulva	Inguinal nodes
Thoracic	Intrathoracic	Internal mammary, mediastinal nodes
Retroperitoneum/pelvis		Pelvic, retroperitoneal nodes
Trunk	Abdominal wall	Inguinal, femoral nodes
	Chest wall	Axillary, internal mammary, and infraclavicular nodes
Other	Biliary	Liver hilar nodes
	Perianal/perineal	Inguinal, pelvic nodes (may be bilateral)

Vaginal embryonal RMS



Botryoid RMS of Prostate	Embryonal RMS of lower limb
	

H&N RMS

Parapharyngeal embryonal RMS


❖Undifferentiated Pleomorphic Sarcoma (UPS) = Malignant fibrous histiocytoma (MFH)

- Most common soft-tissue tumor in adults.
- Age > 60y
- M>F

Location & Distribution:

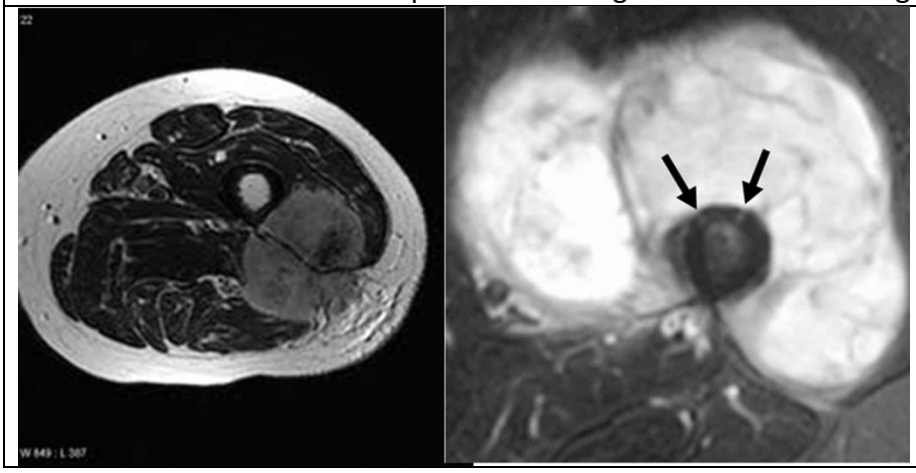
- Almost anywhere in the body
- The most common site of involvement of is
  - ***Retroperitoneum***
  - ***Proximal extremities***

Histological Subtypes:

- Storiform-pleomorphic : most common 50-60%
- Myxoid => Myxofibrosarcoma
- Inflammatory : 5-10%
- Giant cell : 5 - 10%
- Angiomatoid

Imaging Findings:

- Nonspecific
- Identification of a soft-tissue mass with cortical involvement has been considered suggestive of malignant fibrous histiocytoma.
- MR imaging is useful for preoperatively displaying extent of the tumor and its relationship with adjacent structures and neurovascular bundles.
- T1: intermediate signal intensity
- T2: heterogeneous high signal intensity
- Enhancement of solid components with a gadolinium contrast agent



❖Location Specific Soft Tissue Lesions

Lesion	Location
Elastofibroma	Inferior tip of scapula
Glomus tumor	Tufts of finger at nail bed
Baker cyst	Posterior medial aspect of knee, between gastrocnemius and semimembranosus tendons
Plantar fibroma	Associated with plantar fascia
Morton neuroma	Second and third metatarsal interspace

a) Morton Neuroma

- Misnomer; non-neoplastic; does not represent a true neuroma
- Perineural fibrosis around a plantar digital nerve of the foot.
- The condition is thought to be due to chronic entrapment of the nerve by the intermetatarsal ligament

Location

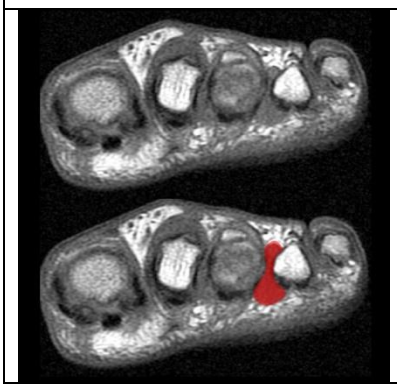
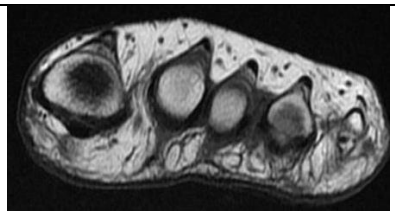
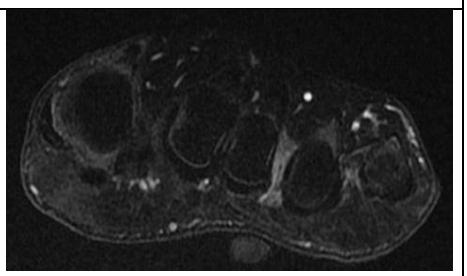
- 3rd web-space (between 3rd and 4th metatarsal heads) is most commonly affected site.
- 2nd web-space is less often involved
- The remaining web-spaces are rarely involved

MRI:

- T1: typically low-to-iso signal
- T2: typically low signal but can sometimes be intermediate in signal
- T1 C+ (Gd): tends to show intense enhancement

Differential Diagnosis of Metatarsalgia / Fore Foot Pain:

- Morton Neuroma
- Intermetatarsal bursa/bursitis
- Metatarsophalangeal joint synovitis/capsulitis
- Changes secondary to a plantar plate tear/disruption
- Metatarsal stress injury / fracture
- Soft tissues tumours, e.g. Schwannoma

Coronal T1	Coronal T2	Coronal T1 FS +C
		

b) Elastofibroma Dorsi

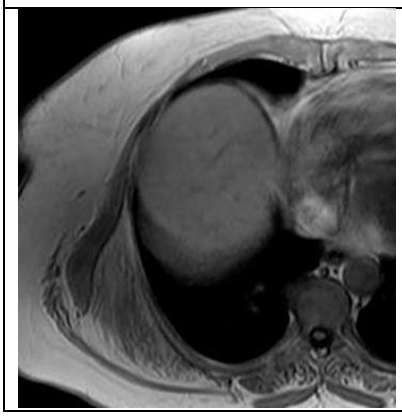
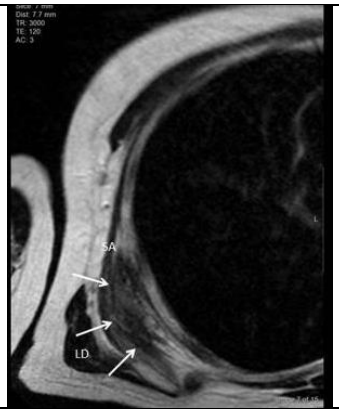
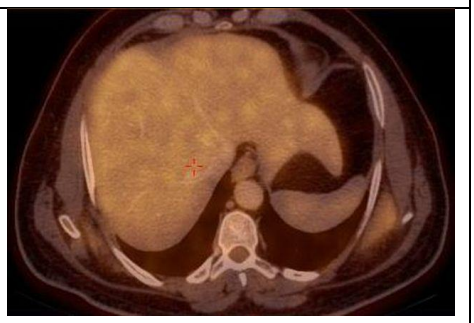
- Benign soft-tissue tumour with a characteristic location and imaging appearance.

Location:

- Infrascapular or subscapular regions, deep to the serratus anterior and latissimus dorsi musculature.
- 60% are bilateral.

Imaging Findings:

- CT: poorly defined soft-tissue mass with attenuation similar to that of the adjacent skeletal muscle.
- MRI: The mass appears as alternating fibrous and fatty components.
- T1
    - Fibrous component: isointense to muscle
    - Fatty component: high signal
- T2
    - Fibrous component: isointense to muscle
    - Fatty component: high signal
- T1 C+: heterogeneous low level enhancement
- PETCT: mild to moderate FDG uptake

Axial T1	Axial T2	PETCT
		

c) Subungual Glomus Tumour

- Benign vascular tumours typically seen at the distal extremities
- Age: middle-aged (4th to 5th decades
- F>>> M

Clinical presentation

- A small firm red-blue nodule under the finger nail

Location

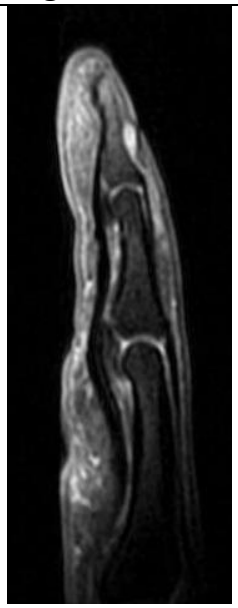
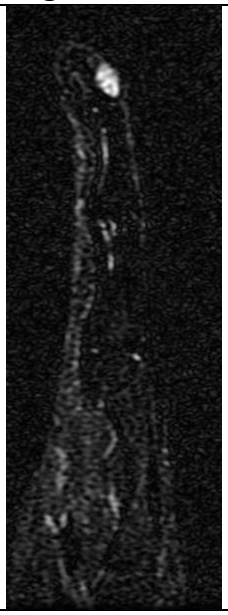
- Approximately 75% occur in the hand

Imaging Findings:

T1: low to intermediate signal

T2: high signal

T1 C+: shows contrast enhancement (usually uniform) due to vascularity

Sagittal T1	Sagittal T2	Sagittal STIR	Axial T1+C FS
			

Musculoskeletal Infection

Osteomyelitis

- is an infection of bone involving the periosteum, cortical bone and the medullary cavity.

- Age : more in children
- Sex: boys > girls
- Bone affected: all bones
- Site of infection: metaphysis

❖ Causative Organism

Infants (≤1 year)

- Group B streptococci
- *Staphylococcus aureus*
- *Escherichia coli*

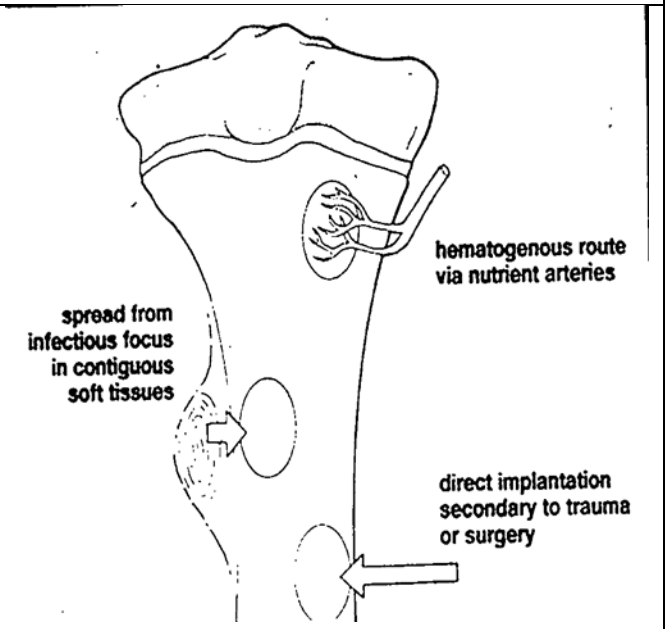
Child/youth (1–16 years)

- *Staphylococcus aureus*
- *Streptococcus pyogenes*
- *Haemophilus influenza*

Adult (>17 years)

- *Staphylococcus aureus*
- *Pseudomonas aeruginosa*
- *Serratia marcescens*
- *Escherichia coli*
- Coagulase negative staphylococci

❖ Route of Infection


hematogenous route via nutrient arteries
spread from infectious focus in contiguous soft tissues
direct implantation secondary to trauma or surgery

❖ **Classification according to Duration**

Acute:	<2weeks
Subacute:	2weeks—6weeks
Chronic:	>6 weeks

❖ Classification

I. Suppurative osteomyelitis:

1. Acute suppurative osteomyelitis
2. Chronic suppurative osteomyelitis

II. Nonsuppurative osteomyelitis

1. Chronic focal sclerosing osteomyelitis
2. Chronic diffuse sclerosing osteomyelitis
3. Garre's chronic sclerosing osteomyelitis (proliferative osteomyelitis)

III. Osteoradionecrosis /Radio osteomyelitis

I- Acute Hematogenous Osteomyelitis

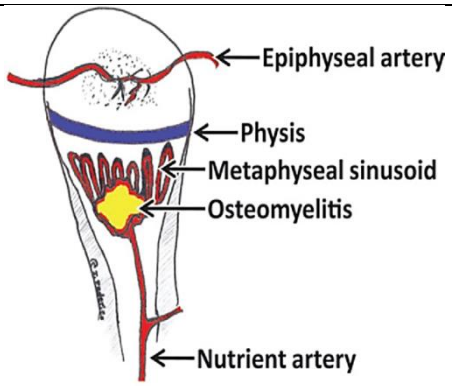
Acute hematogenous osteomyelitis is usually seen in infants and children.

Location:

- Neonates: metaphysis and/or epiphysis
- Children: metaphysis
- Adults: epiphyses and subchondral regions

➢ Metaphysis:

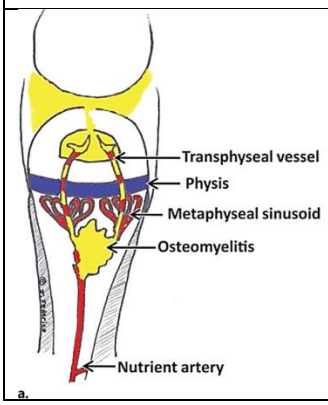
- Nutrient artery terminates in the metaphysis + venous sinusoids with their slow-moving flow
  - ⇨ Metaphyseal osteomyelitis.
- Protection of the epiphysis by the relatively avascular growth plate



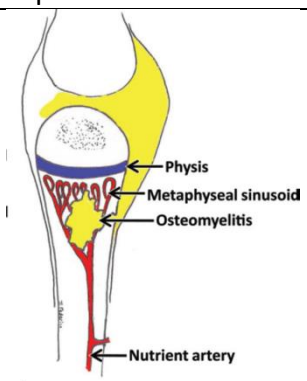
➢ Neonates

Spread of infection from metaphysis => epiphysis through transphyseal vessels that are patent

Spread of infection from metaphysis => joint space through loosely adherent periosteum in the neonate is continuous with the joint capsule.

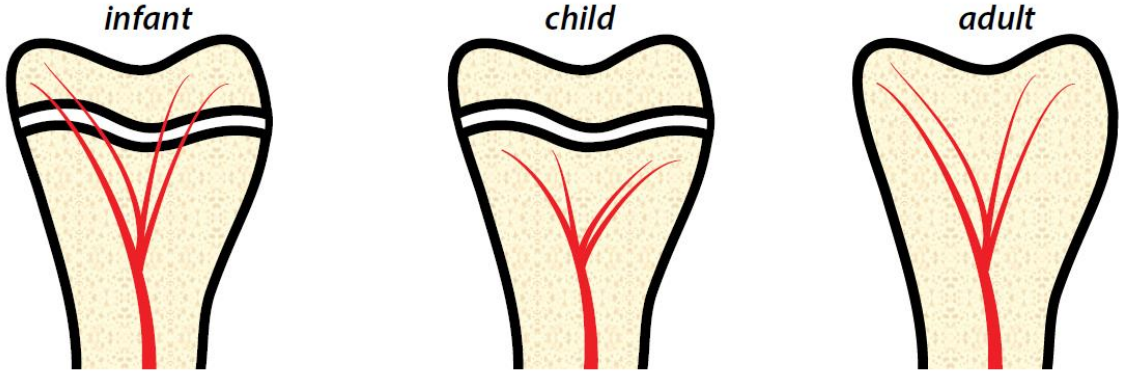


a.



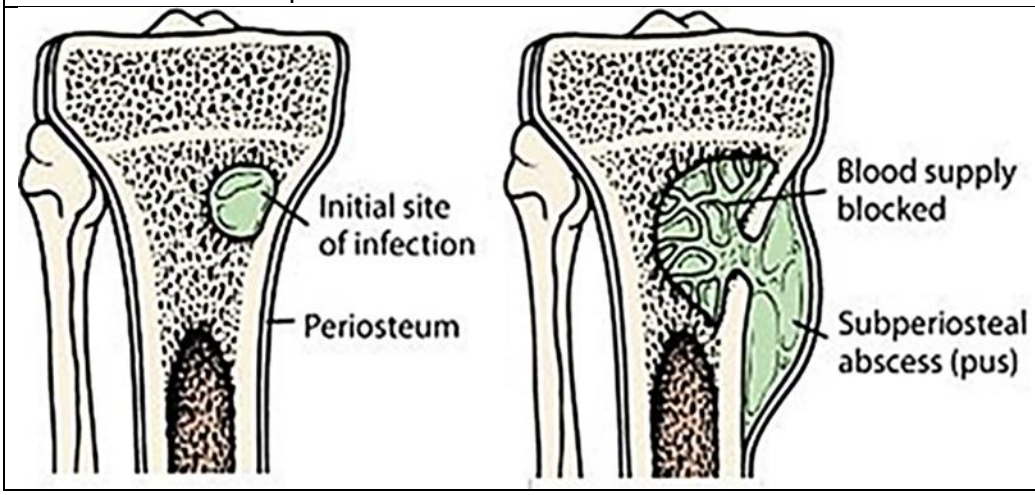
b.

In Infants:	**In older children:**	**In adults:**
Spread of infection from metaphysis => epiphysis through transphyseal vessels that are patent	Infection tends to be isolated to the metaphysis.	The physes are closed but hematogenous metaphyseal infection is uncommon.



Pathology:

- Hematogenous osteomyelitis occurs from the inside out:
- Beginning with infection of the medullary cavity.
- Secondary involvement of the cortex occurs as bacteria spread through Haversian and Volkmann canals into the periosteum and subsequently the soft tissues.
- Formation of subperiosteal abscess



Clinical Picture:

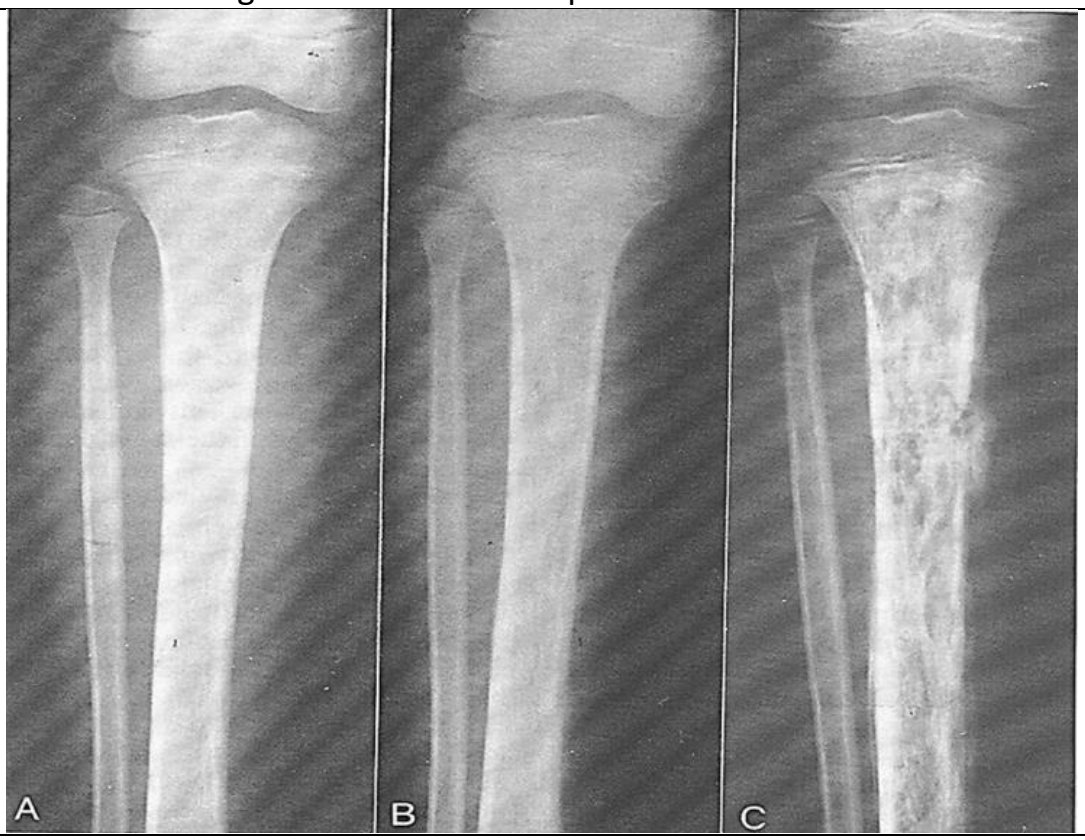
- High grade fever
- Child refuses to use limb (Pseudo-pralysis)
- Local red-hot-tender

Laboratory Findings:

- Elevated WBC – CRP – ESR
- Aspiration / Culture samples from infected site
- Blood culture: positive in 50% of cases

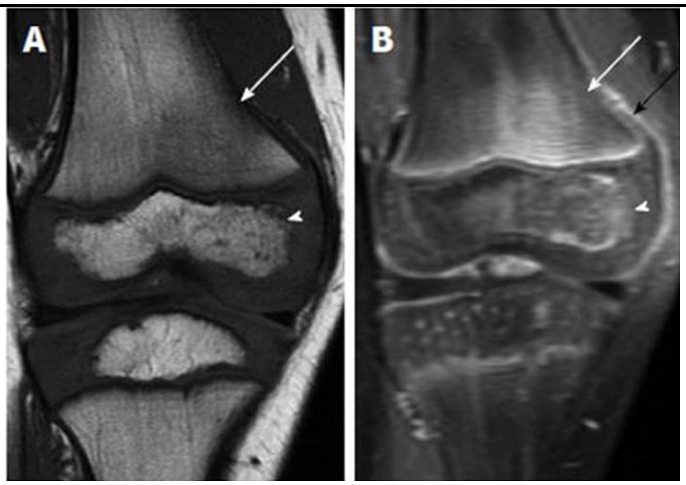
X-ray:

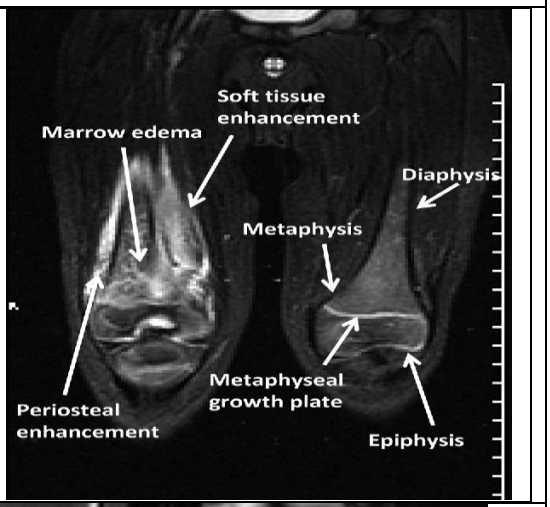
- Normal (7-10 days)
- It takes 10-21 days for osseous lesion to be visible on conventional radiography; because 30-50% reduction of bone density must occur before being radiologically apparent
- Localized osteopenia
- Cortical irregularity – tunneling – destruction – permeation
- Lamellar Periosteal reaction
- Endosteal scalloping
- Soft tissue swelling + obliteration of fat planes

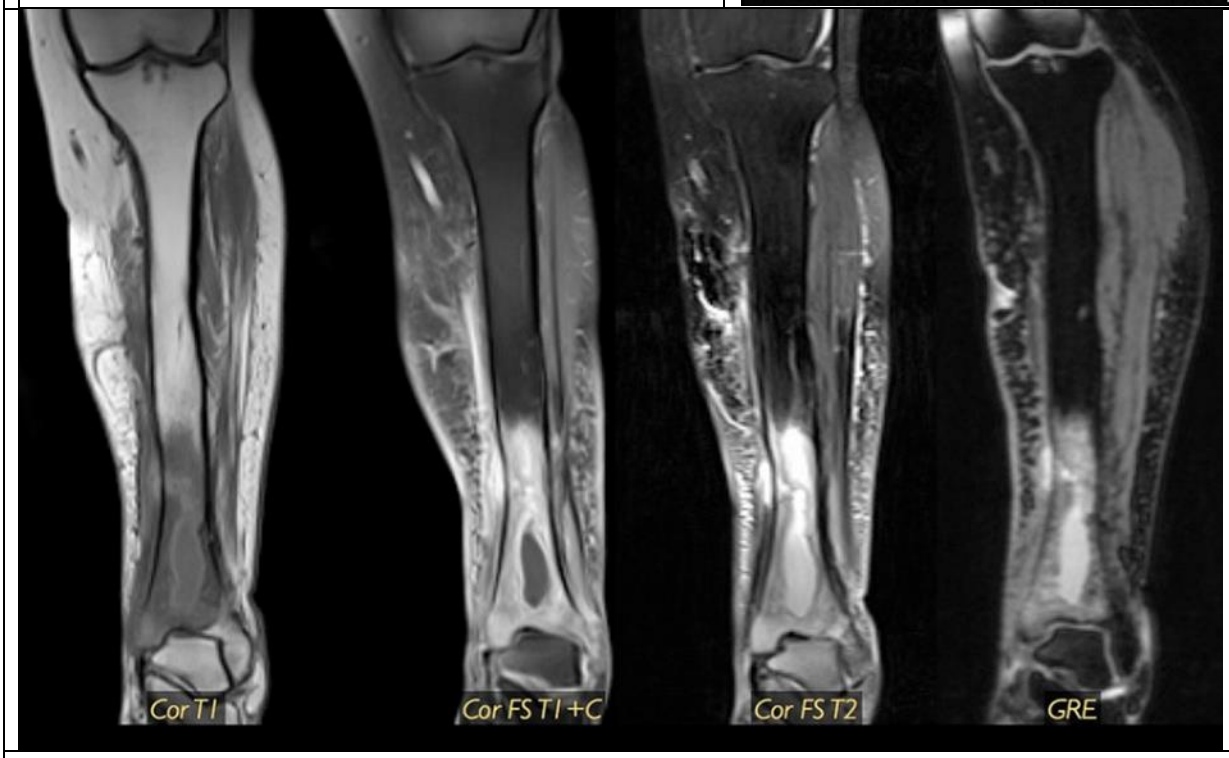


❖ MRI:

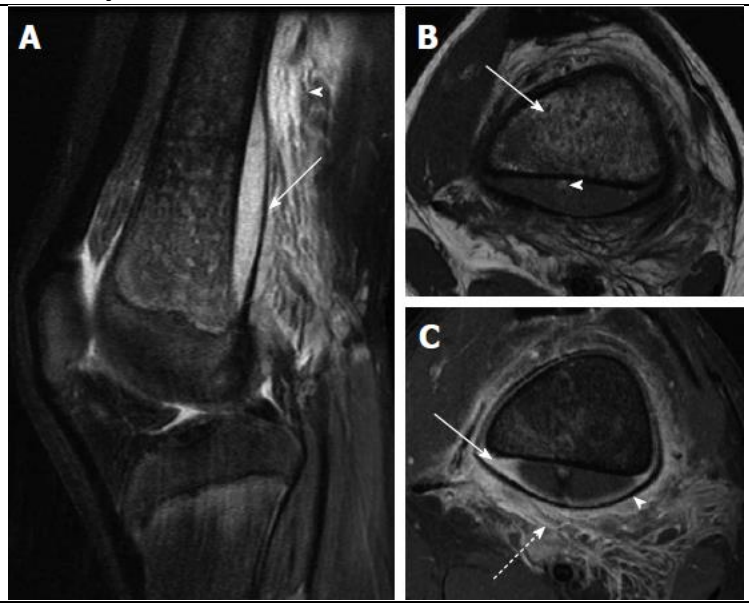
- Bone marrow edema
- Central fluid signal
- Cortical destruction
- Soft tissue edema



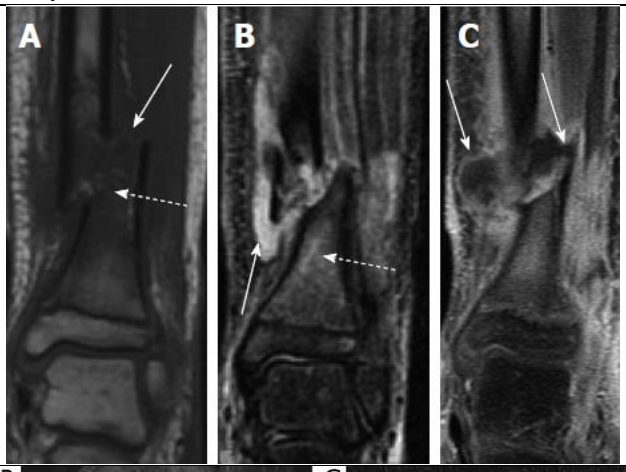




Osteomyelitis with Subperiosteal Absecc



Osteomyelitis secondary to fracture



❖Bone Scan

- Three-phase Tc-99m MDP bone scan becomes positive within 24–48 hours after the onset of symptoms.
- Acute osteomyelitis is positive on all three phases (flow, blood pool, and delayed).

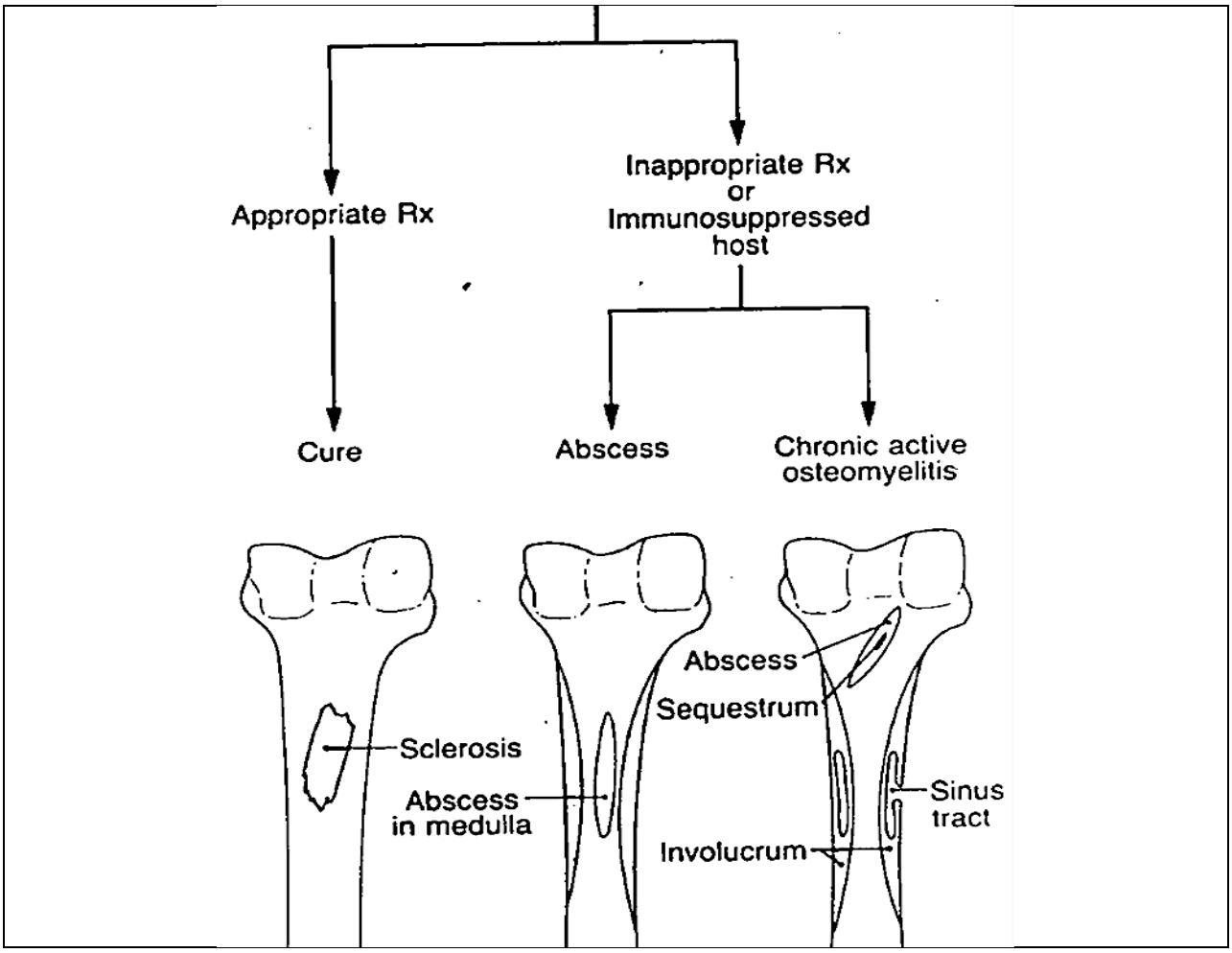
- Combining WBC and sulfur colloid scintigraphy adds specificity in the evaluation of osteomyelitis because bone marrow is replaced by infection and white cells.
- Actively infected bone marrow will show discordantly increased uptake on the WBC scan and reduced activity on sulfur colloid.
- WBC scan can be performed with either Indium-111-WBC or Tc-99m-HMPAO-WBC.
- Indium WBC scan has higher radiation dose, takes 24 hours to perform, and the image has more noise.
- The disadvantage of Tc-99m-HMPAO is its tendency to dissociate, leading to genitourinary excretion of radiotracer.

- Technitium-99m imaging is very sensitive , it is the choice for acute hematogenous osteomyelitis, the overall accuracy being 92%.

Bone scan revealing hot spot in right tibia

- Ga^{67} scintigraphy provides the best way to detect vertebral osteomyelitis radiologically.

- In^{111} labeled leucocyte imaging is the test of choice for osteomyelitis elsewhere in body.



Complications:

- Septicemia & metastatic abscesses
- Septic arthritis
- Growth disturbance (children)
- Pathological fracture
- Chronic osteomyelitis

II- Acute Contiguous Osteomyelitis (See Diabetic MSK Complication)

- One of the most common causes of adult osteomyelitis is contiguous spread of a diabetic foot ulcer to the bones.

III- Subacute Osteomyelitis

- Longer history 2-6w
- Less virulent organism
- More resistant patient
- Insidious onset, Mild symptoms
- Pain is the most consistent symptom
- No systemic constitutional symptoms

classification

Type	Gledhill Classification	Robert et al. Classification
I	Solitary localized zone of radiolucency surrounded by reactive new bone formation	Ia—Punched-out radiolucency
		Ib—Punched-out radiolucent lesion with sclerotic margin
II	Metaphyseal radiolucencies with cortical erosion	—
III	Cortical hyperostosis in diaphysis; no onion skinning	Localized cortical and periosteal reaction
IV	Subperiosteal new bone and onion skin layering	Onion skin periosteal reaction
V	—	Central radiolucency in epiphysis
VI	—	Destructive process involving vertebral body

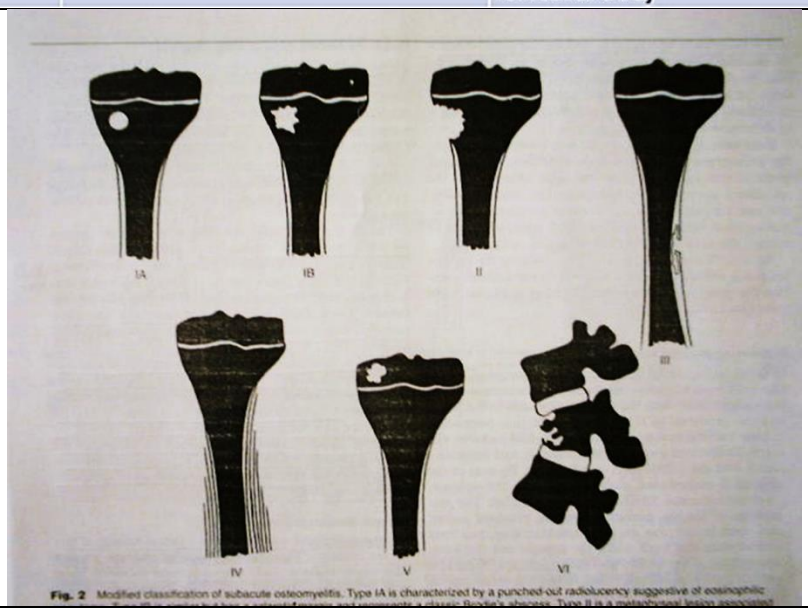


Fig. 2 Modified classification of subacute osteomyelitis. Type IA is characterized by a punched-out radiolucency suggestive of eosinophilic

❖ Brodie's Abscess

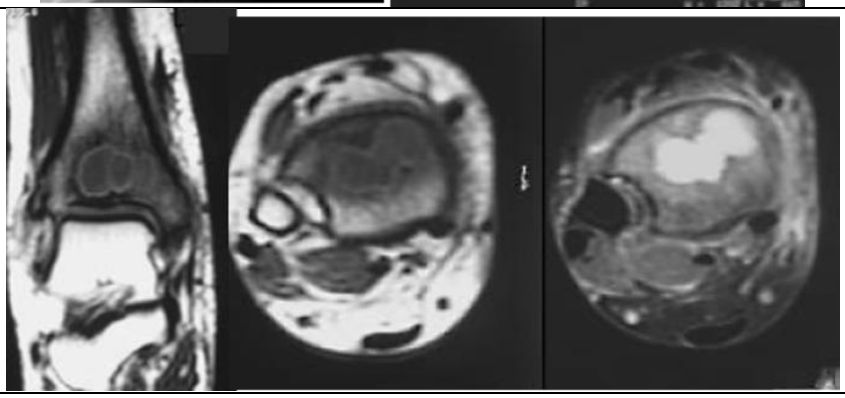
- Intraosseous abscess related to a focus of subacute pyogenic osteomyelitis.
- A circumscribed rounded / oval cavity containing pus and dead bone (sequestra) surrounded by sclerosis.

Location:

- Proximal/distal tibial / femoral metaphysis (most common)
- carpal and tarsal bones

Radiological Findings:

- A well-defined lytic lesion
- Oval configuration that is oriented along the long axis of the bone
- Surrounded by a thick dense rim of reactive sclerosis that fades imperceptibly into surrounding bone
- Lucent tortuous channel extending toward growth plate prior to physeal closure (pathognomonic)
- Periosteal new-bone formation
- +/- adjacent soft-tissue swelling
- The "penumbra sign" a rim lining of an abscess cavity with higher signal intensity than that of the main abscess on T1



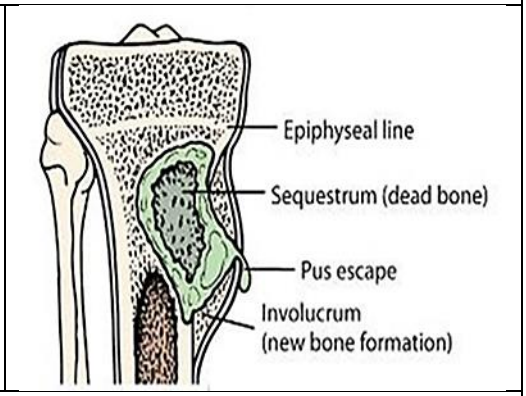
H
R
A
L
F
R

IV- Chronic Osteomyelitis

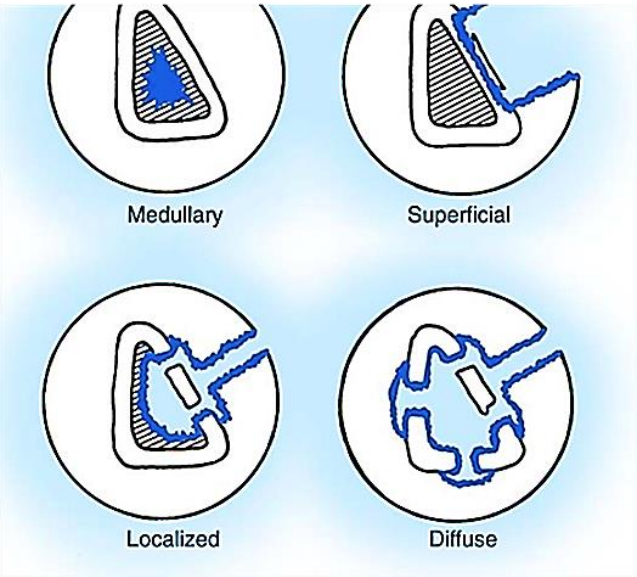
Types

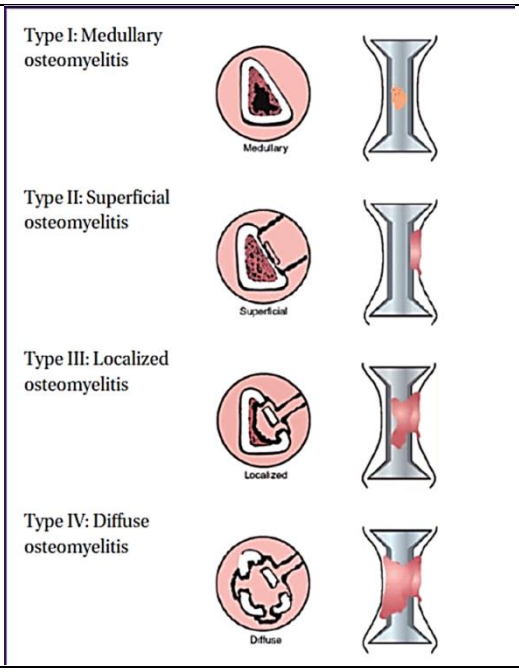
- A complication of acute Osteomyelitis
- Post traumatic
- Post operative

- **Sequestrum**= detached necrotic bone
- **Cloaca formation** = space in which dead bone resides.
- **Involucrum** = is living bone surrounding necrotic bone.
- **A cloaca** = is an opening on the involucrum
- **Sinus tract**= is an opening from the infection to the skin surface.



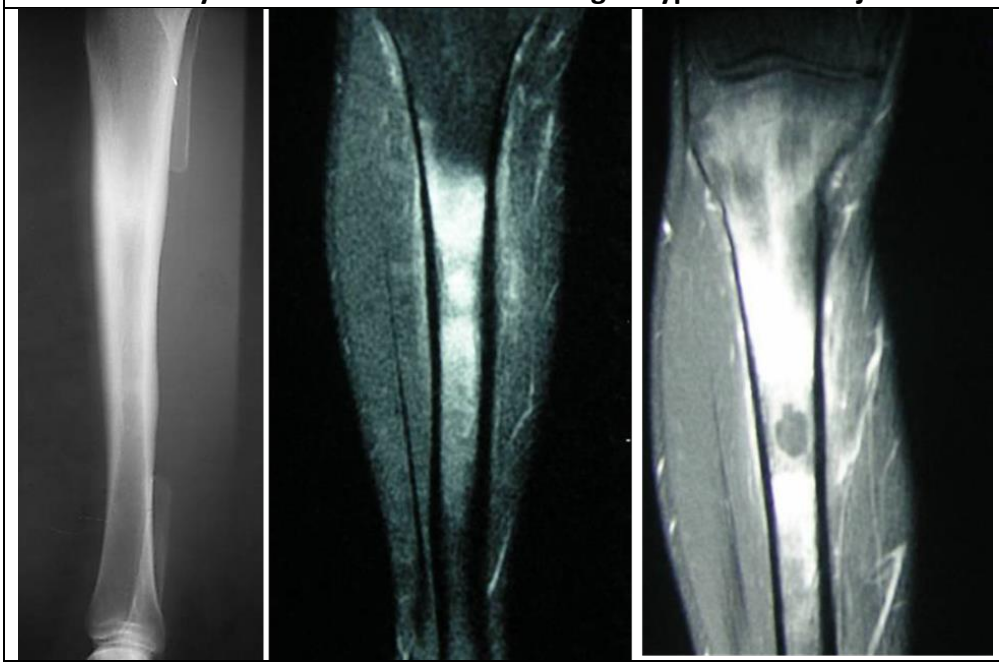
Cierny-Mader
Anatomical Classification



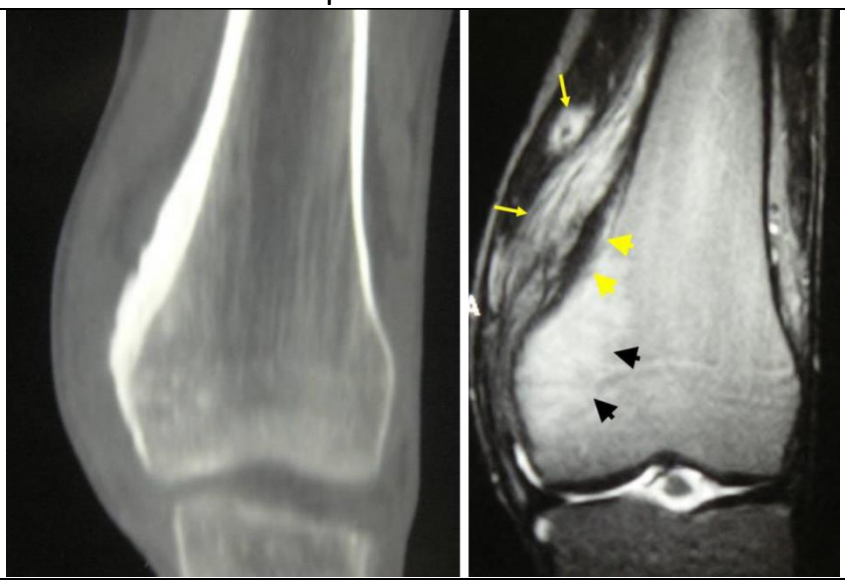


Anatomical type
Type I: Medullary
Type II: Superficial
Type III: Localized
Type IV: Diffused
Physiological condition
A: Healthy
B: Systemically compromised, Bs
Locally compromised, Bl
Systemically and locally compromised, Bls
C: The majority of damage is due to treatment rather than disease
Factors influencing immunity, metabolism, and local blood supply
Systemic factors (Bs): Malnutrition, chronic renal failure, liver failure, diabetes mellitus, chronic hypoxia, neonate/elderly, malignancy, immunosuppression or immune deficiency.
Local factors (Bl): Chronic lymphedema, venous stasis, major vessel compromise, arteritis, large scar formation, post-radiation fibrosis, small-vessel disease, neuropathy or smoking

Type 1: Inflammatory focus in the medullary cavity filled with necrotic tissues and surrounded by bone marrow edema and slight hyperemia in adjacent soft tissues

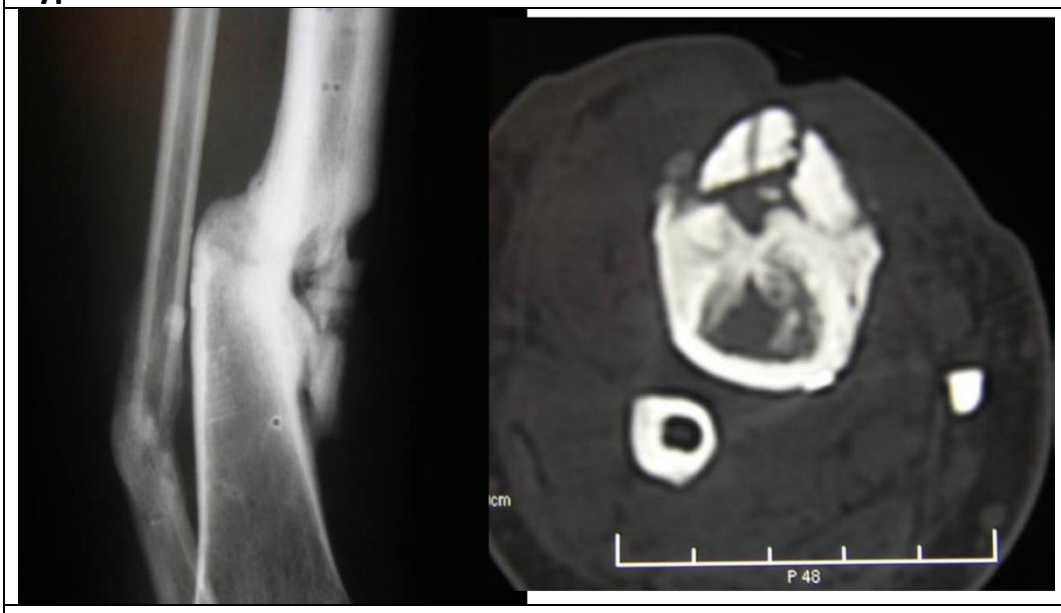


Type 2: Focal cortical thickening & sclerosis
Soft tissue inflammatory changes
Mild bone marrow edema
No sequestration nor cortical disruption

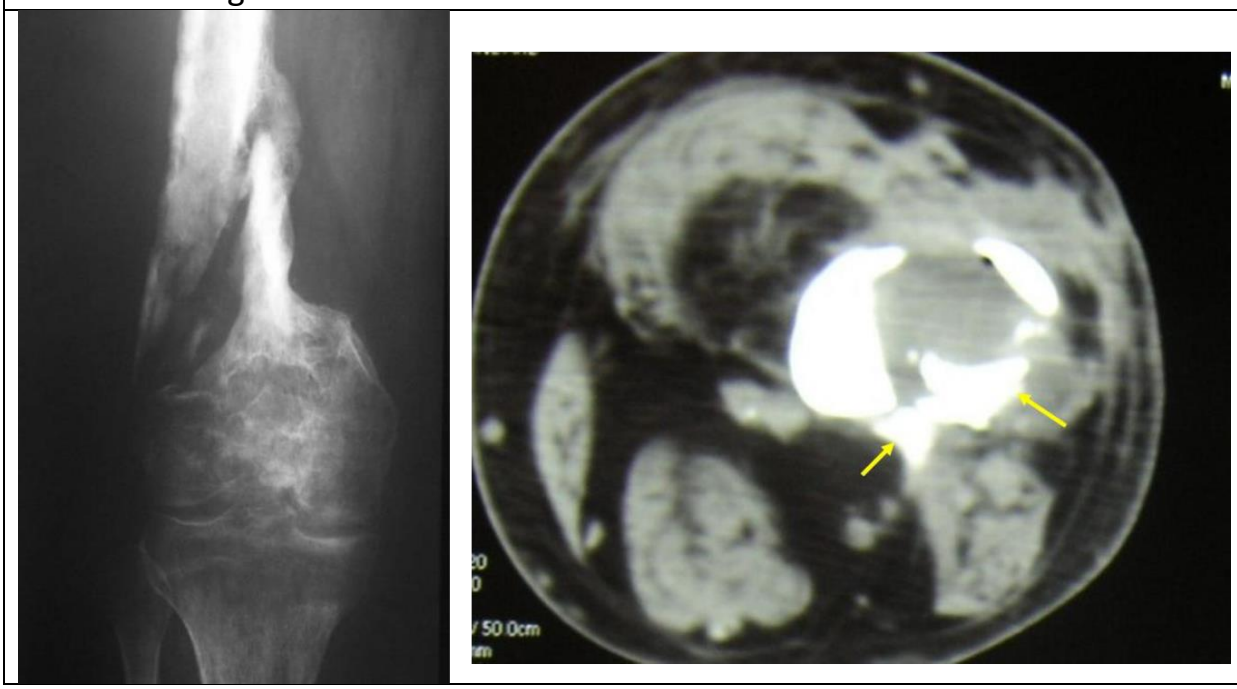


Type 3: Ring Sequestrum

Type 4: Malunioned fractures + Cortical sclerosis + several cortical sequestra

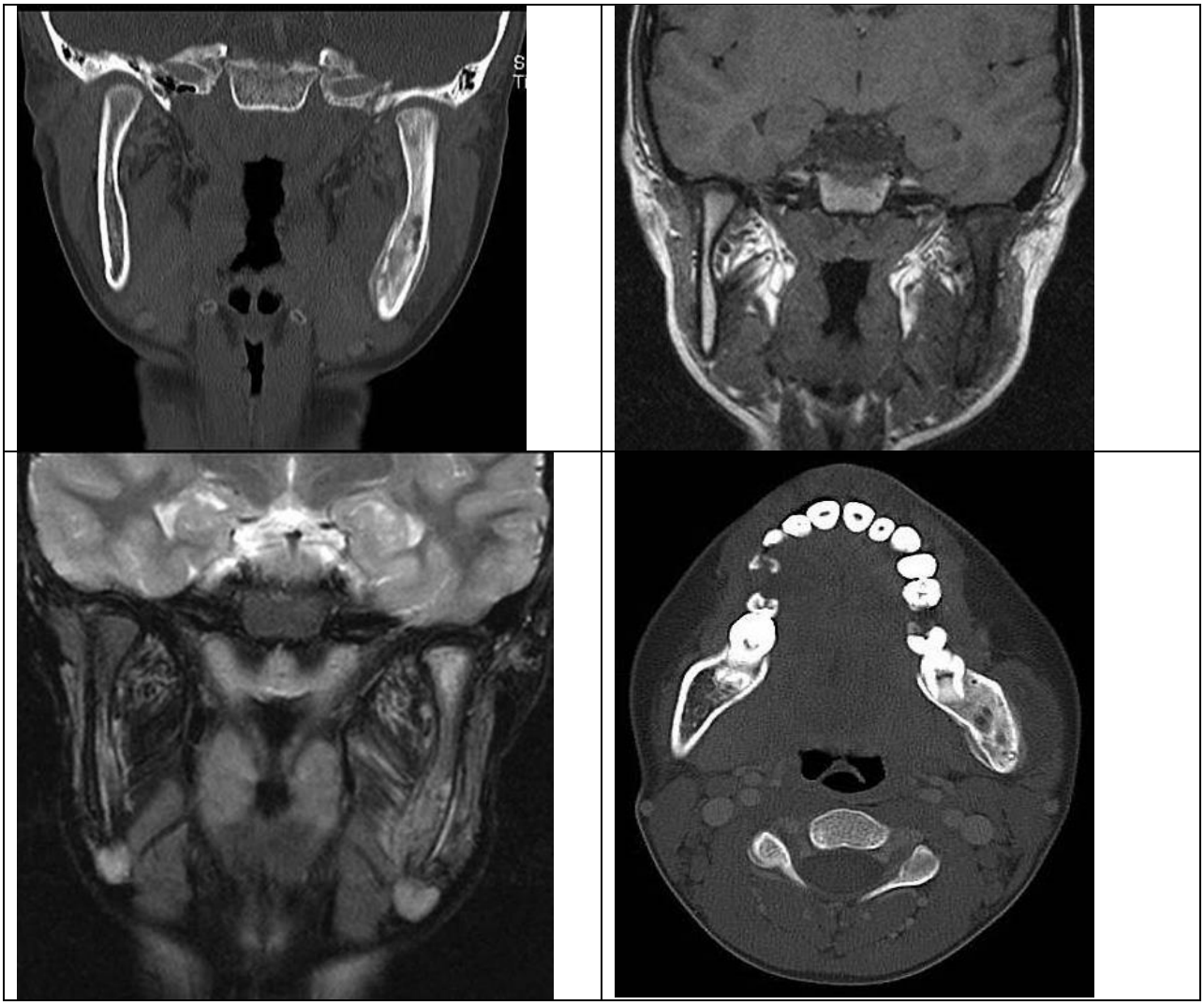


Type 4: Non-union distal femoral shaft fracture
Cortical destruction + bony sequestra
Extensive inflammatory infiltrate in the marrow cavity and soft tissues of the thigh
+ Intraosseus gas and fluid collections



V- Sclerosing Osteomyelitis of Garré

- Specific type of chronic osteomyelitis.
- It mainly affects children and young adults.
- It typically affects the mandible and is commonly associated with an odontogenic infection resulting from dental caries



VI- Chronic Recurrent Multifocal Osteomyelitis (CRMO)

- is an idiopathic inflammatory bone disorder
- Children and adolescents.
- It is often a diagnosis of exclusion once underlying infection and neoplasia has been ruled out.

Location:

- Metaphyses or metaphyseal equivalents of the long bones.
- Most frequently in the tibia. However, a wide range of skeletal site involvement has been reported.
- Clavicle involvement is a characteristic finding since this is an uncommon location for haematogenous osteomyelitis.

Imaging Findings:

- Bone marrow edema
- Periostitis
- Soft tissue oedema
- Extension across the physis
- Areas of post-gadolinium enhancement

Findings that should raise the possibility of haematogenous osteomyelitis over CRMO include:

- Large fluid collection
- Abscess
- Fistulous tract
- Bony sequestrum

a
b
A
B

Muscle Signal

Muscle Edema:

- Muscle injury: Muscle strain – Muscle contusion
- Inflammatory myopathy: Polymyositis and dermatomyositis
- Infectious myositis
- Radiation therapy
- Subacute denervation
- Compartment syndrome
- Early myositis ossificans
- Rhabdomyolysis
- Sickle cell crisis.

Muscle Fatty Infiltration:

- Chronic denervation
- Chronic disuse
- Muscular Dystrophy

Muscle Mass Lesion

- Neoplasms
- Intramuscular abscess
- Myonecrosis
- Muscle hematoma
- Myositis ossificans
- Muscular sarcoidosis
- Parasitic infection.

1) Muscle Trauma

A- Indirect Muscle Injury

i) Delayed-Onset Muscle Soreness (DOMS):

- DOMS is a type of overuse injury that does not become symptomatic until hours or days after the overuse episode.
- DOMS in contrast with a muscle strain or contusion, which usually is immediately painful.
- DOMS develops 1-2 days following exercise and resolves in 1-2 weeks

ii) Muscle Strain

- Muscle strains are injuries of the musculotendinous junction (MTJ) caused by overly forceful muscle contraction.

Muscle strain occurs most frequently in muscles that:

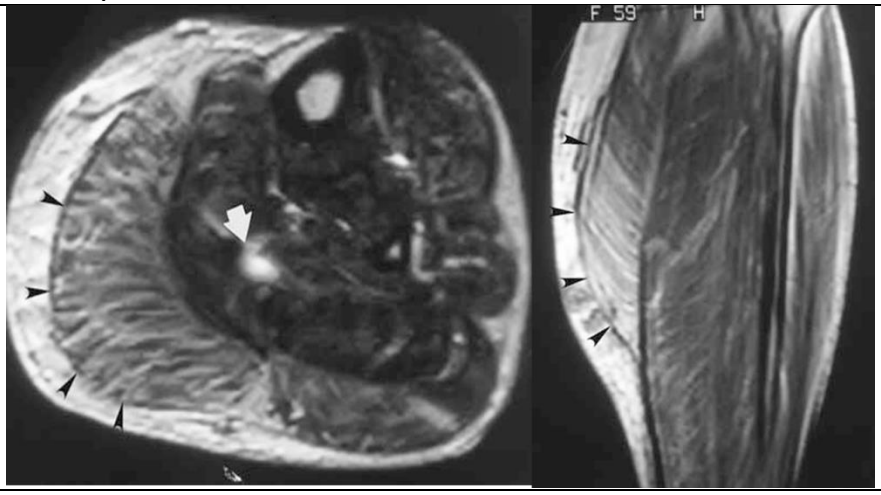
- Cross two joints
- Contain fast-twitch fibers
- Contract during elongation (eccentric contraction).

Common muscles:

- Hamstring (Biceps femoris), quadriceps (Rectus femoris), gastrocnemius and biceps brachii muscles.

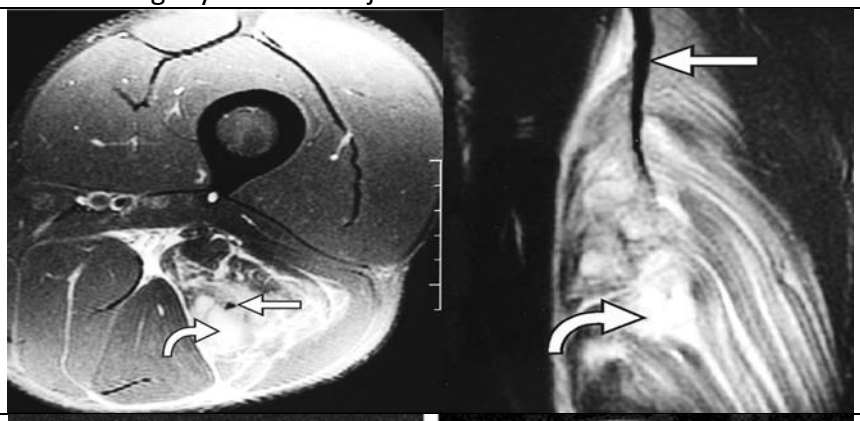
Grade I Muscle Strain:

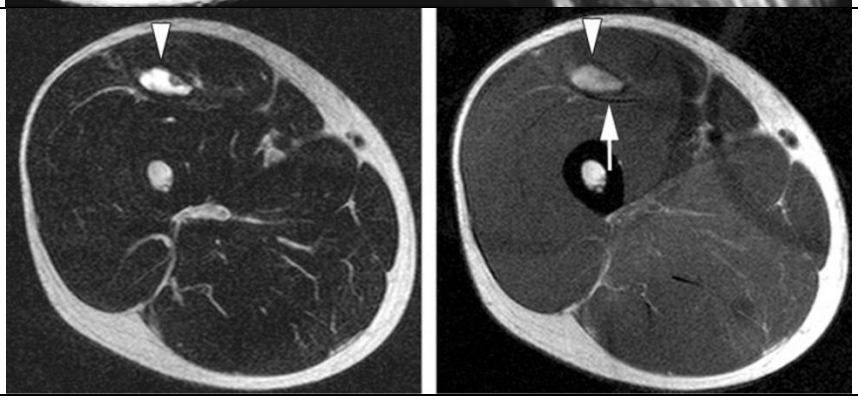
- MRI: Feathery interstitial ↑ signal on T2 & STIR WIs due to interstitial edema/hemorrhage present at the myotendinous junction and extend into the adjacent muscle fascicles, producing a feathery appearance on MR images.
- Intermuscular/ perifascial edema inbetween muscles.



Grade II Muscle Strain = Partial Tear:

- Focal disruption of muscle fibers
- Focal mass like lesion or stellate defect within the muscle.
- Partially torn myotendinous junction
- Thinning + irregularity + laxity of the tendon.
- Hematoma surrounding myotendinous junction.





Grade III Muscle Strain = Complete Tear

- Discontinuity of muscle and tendon traversing the muscle.
- Retraction of fragments.
- Hematoma in gap between retracted fragments.

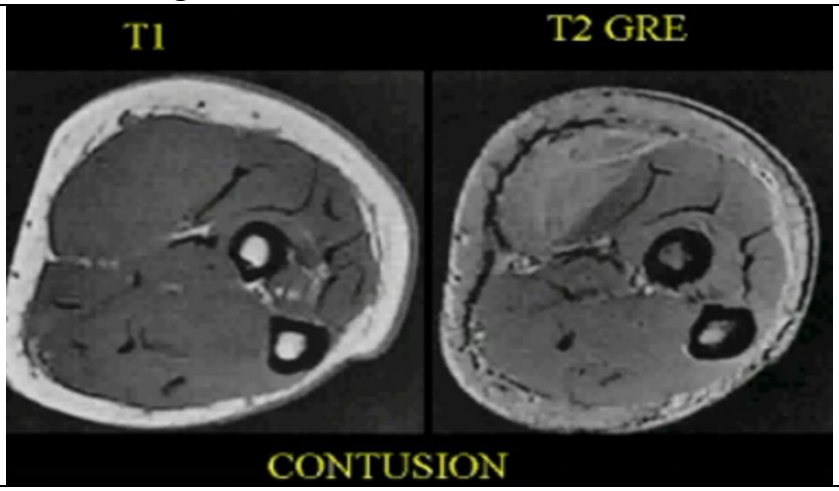
Complete tear of quadriceps tendon.	***Avulsion injury of patellar tendon.***

B-Direct Muscle Injury

i. Blunt trauma => Muscle Contusion

MRI Features of Contusion:

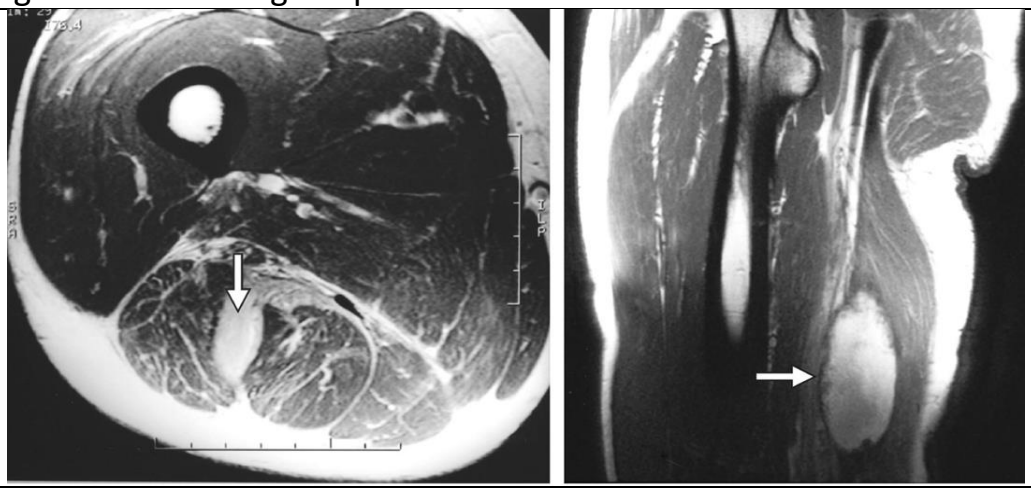
- T1: Normal signal
- T2/STIR: Faethery interstitial increased signal pattern
- Focal muscle enlargement + No mass formation



ii. Penetrating trauma => Muscle Laceration + Hematoma

MRI features of Hematoma:

- Focal muscle enlargement.
- Focal confined mass like collection of blood.
- No muscle fibers coursing through it.
- Signal of blood is age dependent.



C- Muscle Herniation

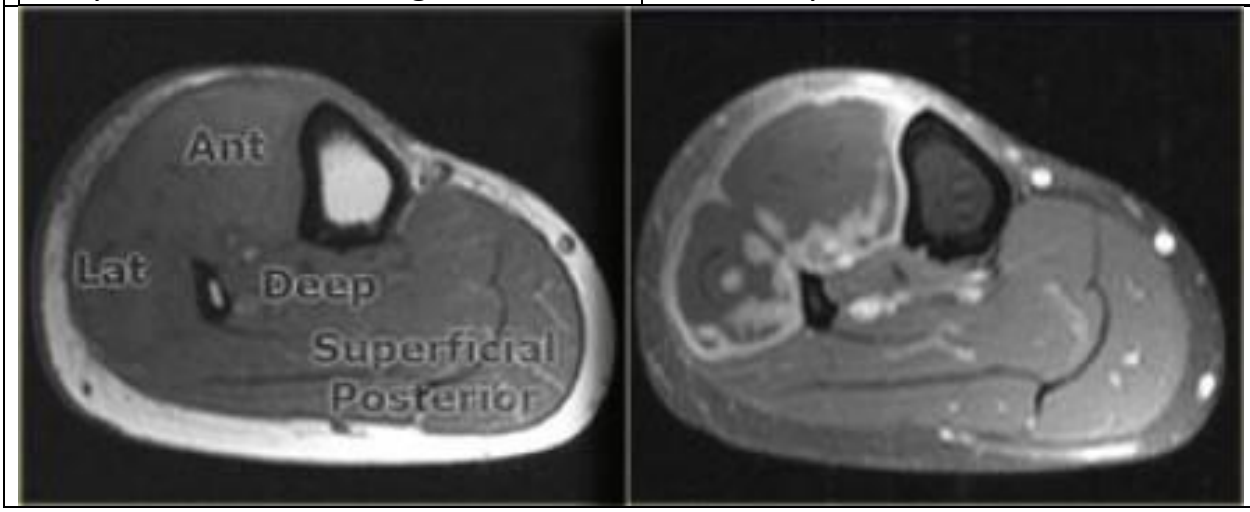
- Muscle herniates through fascial defect, protruding upon muscle contraction.
- A fascial tear is a typical sports injury
- Most commonly involves the calf.
- This type of muscle injury is well evaluated with ultrasound, because it is a dynamic examination.
- MRI: normal muscle signal protruding through fascial defect.

D- Compartment Syndrome

- Compartment syndrome is a limb-threatening and life-threatening condition observed when perfusion pressure falls below tissue pressure in a closed anatomic space.
- A fasciotomy procedure with incision in the skin and the muscle fascia is necessary to release the pressure and regain normal function of the capillaries.
- Compartment syndrome progresses to rhabdomyolysis if untreated.

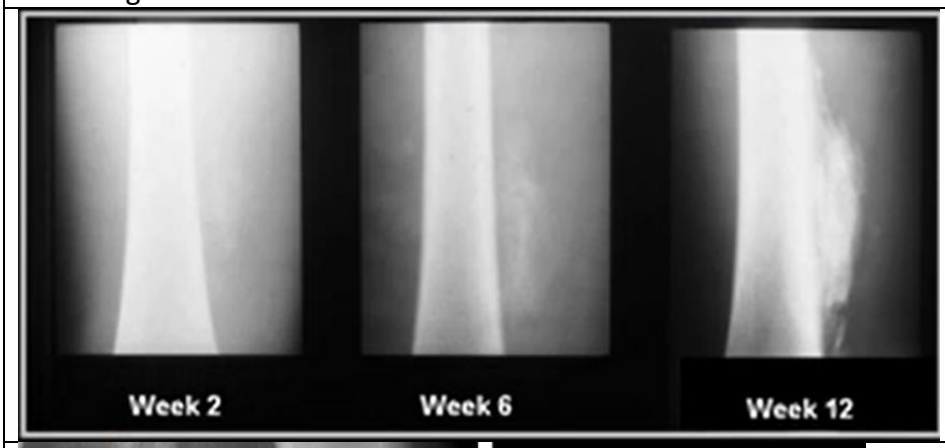
- Trauma => Fracture + edema /hemorrhage in closed space => Increased pressure

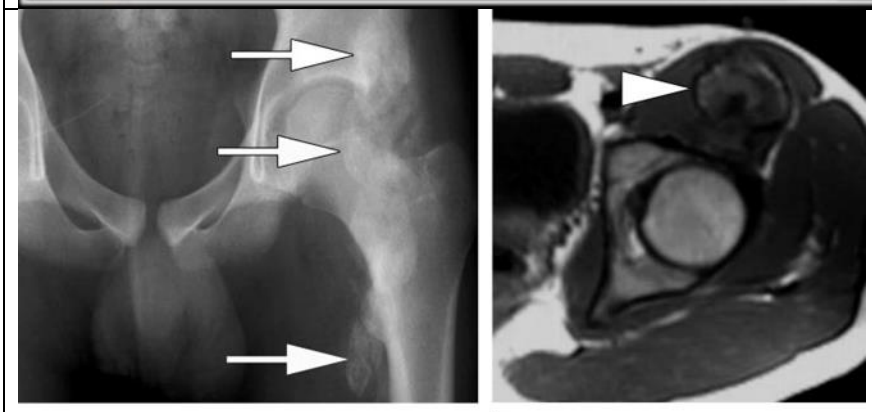
Early => Increased MRI signal	Late => Myonecrosis

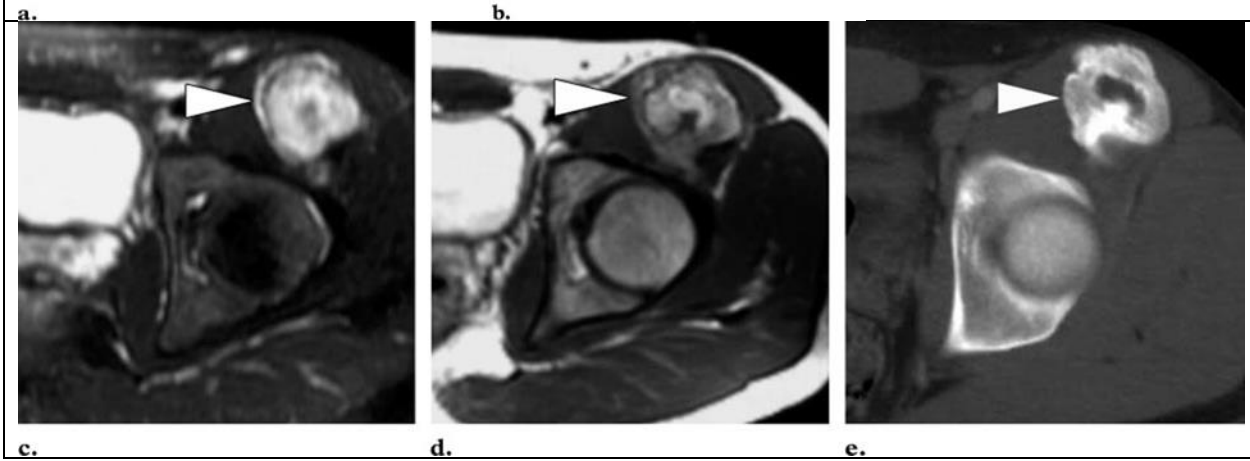


E- Myositis Ossificans

- Localized to site of injury
- Calcification is rarely seen on radiographs in the first few weeks but can become apparent 3–8 weeks after onset, starting peripherally and progressing centrally in a zonal pattern
- Mature to bone
- Along axis of muscle.



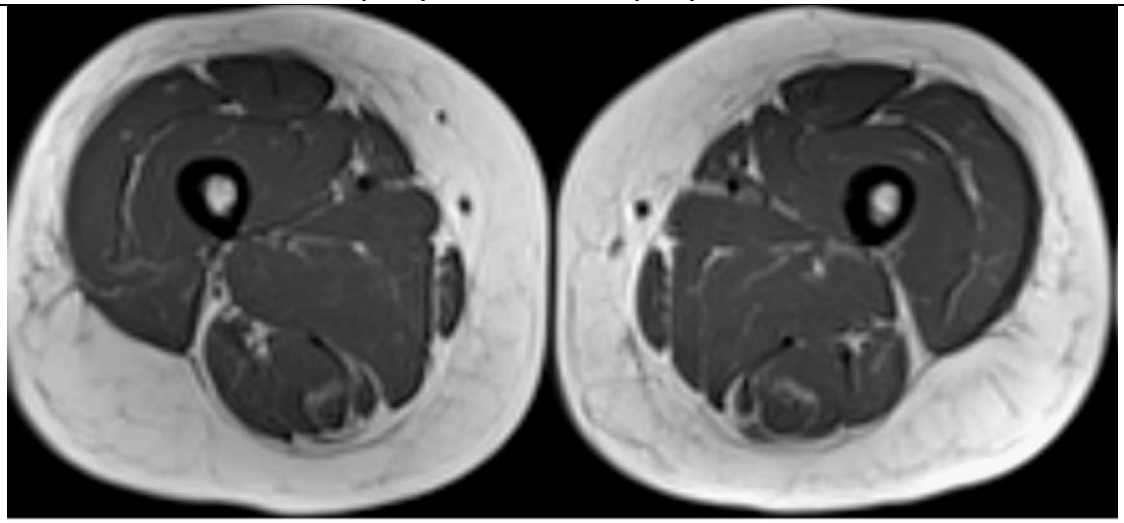




2) Inflammatory Myopathy:

- **Dermatomyositis (DM)**
- **Polymyositis (PM)**
- **Inclusion body myositis (IBM)**

- Insidious onset gradually progressive proximal muscle weakness.
- Distribution: proximal muscles, particularly those in the pelvis and thighs (anterior group)
- T2/STIR: Bilateral and symmetric edema.
- Skin lesions often accompany inflammatory myositis



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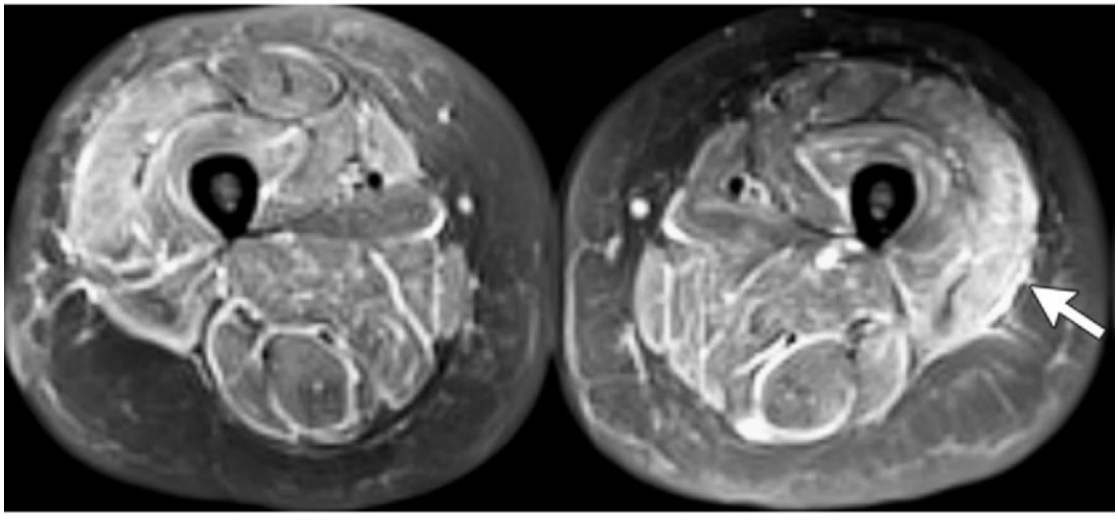

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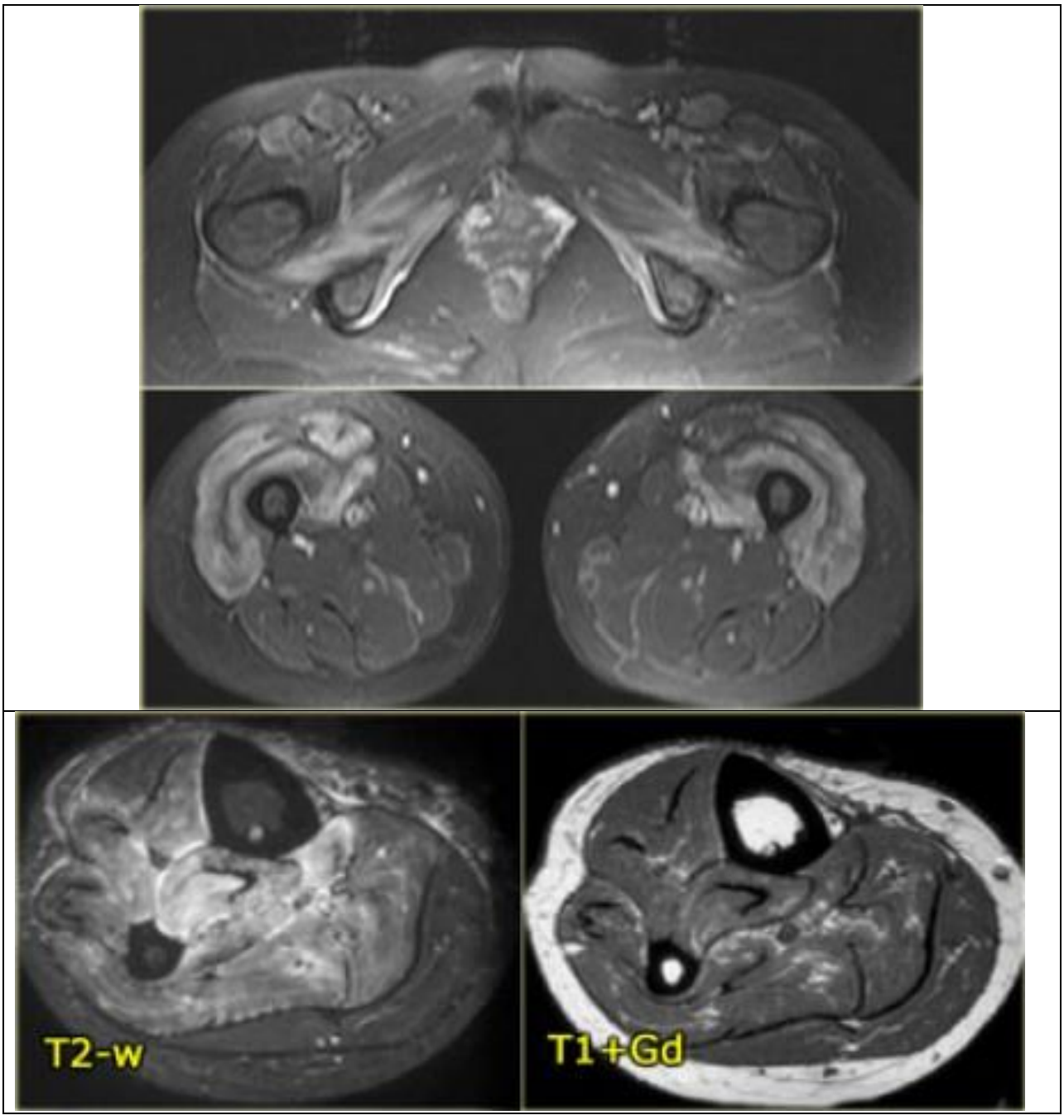
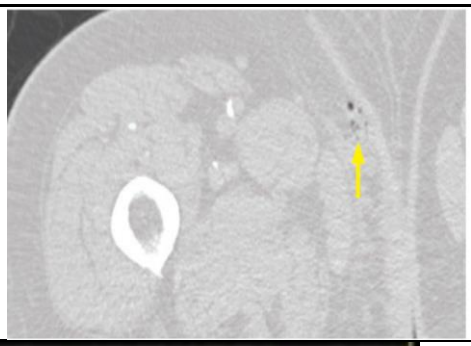
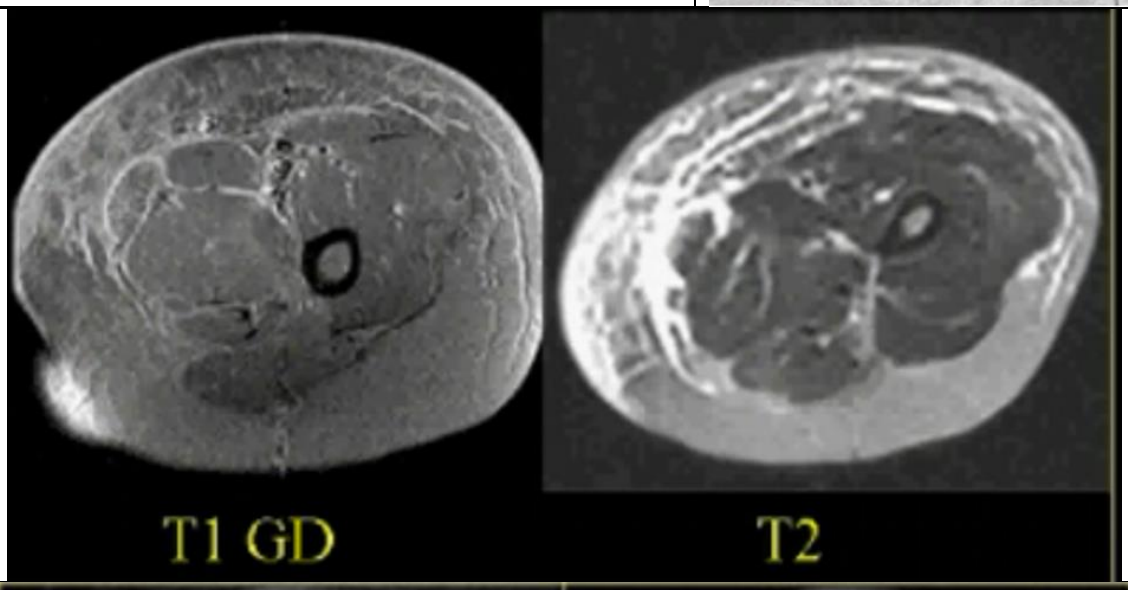

T2-w
T1+Gd

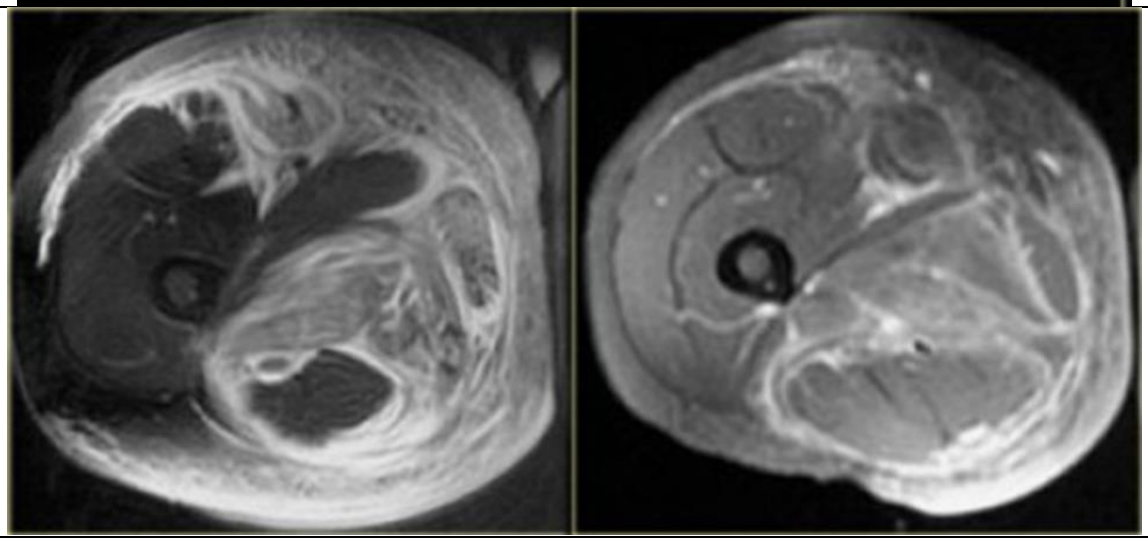
3) Necrotizing Fasciitis

- Rare infection of the deeper layers of skin and subcutaneous tissues, easily spreading across the fascial plane within the subcutaneous tissue

- Aggressive soft tissue infection caused by Clostridium or other gram-positive rods.
- It is a surgical emergency, requiring immediate debridement.
- The characteristic radiographic and CT finding of necrotizing fasciitis is gas bubbles in the soft tissues.

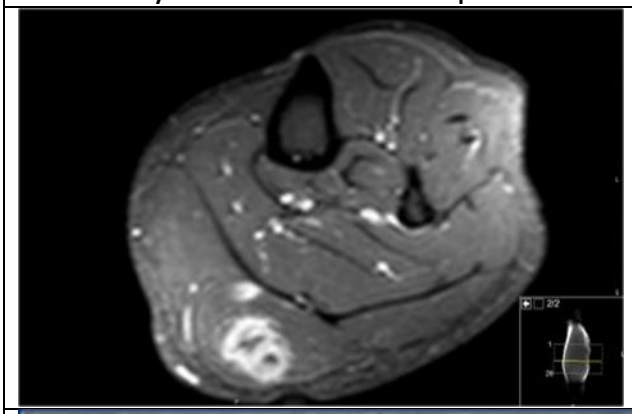


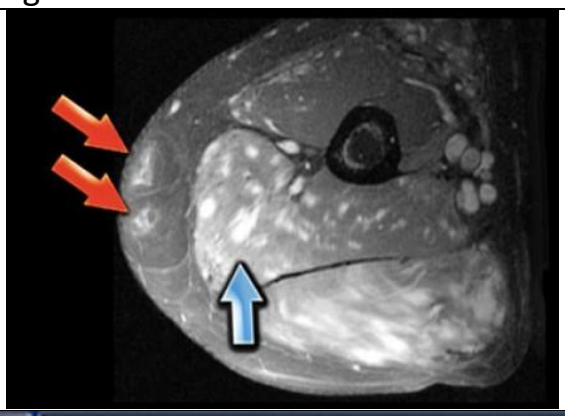


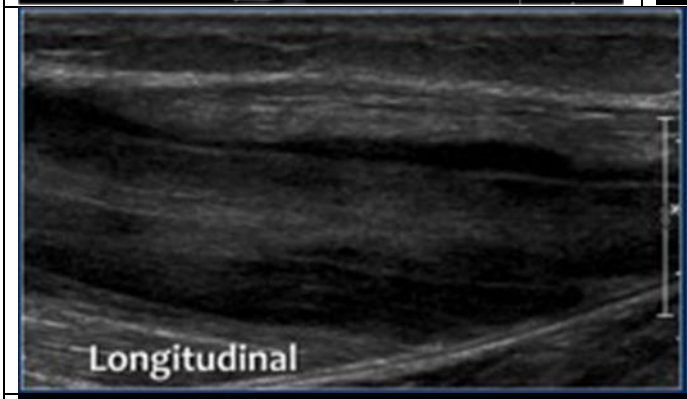


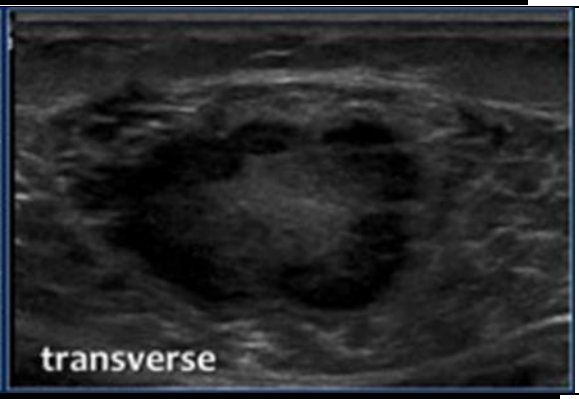
4) Sarcoidosis

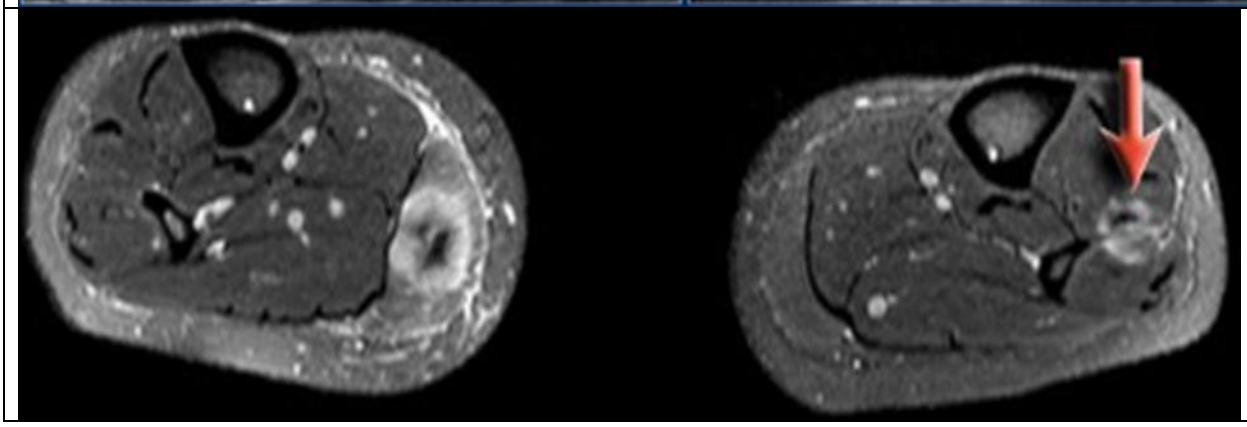
- 1-2% of patients with active sarcoid will have muscle involvement and there are always skin changes on the overlying skin
- The enhancement pattern is referred to as the 'Stars and Stripes' pattern, mostly because of the stripes on the long axis of the muscle.











5) Muscular Dystrophy

- It is diagnosed clinically usually in children, with patients experiencing symmetrical muscle weakness, pseudohypertrophy of the calves and difficulty in standing up.
- The muscle initially is edematous and then rapidly becomes atrophic.
- There are many types of muscular dystrophy.
- The most common type is Duchenne.

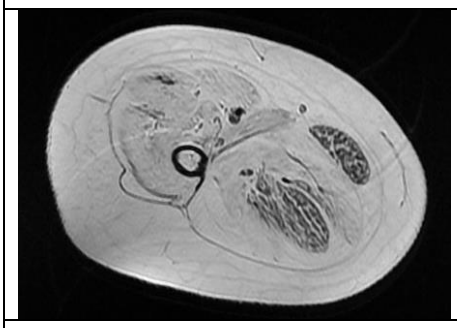
Lower limb and pelvic musculature:

- Early involvement of the gastrocnemii muscles
- Eventual involvement of the gluteus maximus, gluteus medius and adductor magnus muscles,
- Followed by involvement of the psoas, iliacus, quadriceps, rectus femoris, biceps femoris, peroneus longus, and soleus muscles
- There is characteristic relative sparing of the sartorius, gracilis, semitendinosus, semimembranosus, and tibialis posterior muscles, even in advanced stages of the condition

Upper limb musculature:

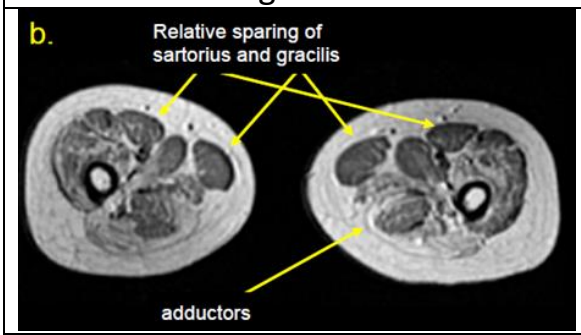
- Preferential involvement of the triceps brachii, biceps brachii, teres major, supraspinatus, infraspinatus, and subscapularis muscles
- The deltoid muscle is usually spared

Axial T1

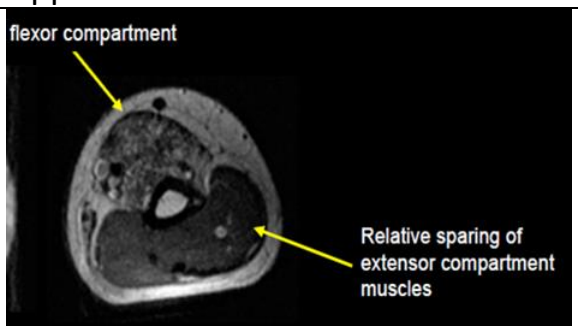


Pelvic Muscles

Lower Limb: Thigh



Upper Limb: Arm



Muscle Denervation &

Peripheral Nerve Entrapment

- Entrapment neuropathies are a group of disorders of the peripheral nerves that are characterized by pain and/or loss of function (motor and/or sensory) of the nerves as a result of chronic compression.

Causes of Nerve compression

a) Static causes

- Abnormal bone alignment (fractures or joint instability).
- SOL (callus, bony spurs, hematoma, bursa, ganglion cyst, soft tissue tumors)
- Inflammation and edema (tenosynovitis)
- Mechanical friction.

b) Dynamic causes

- Repetitive movement - muscle hypertrophy - nerve compression.

Diagnosis of nerve compression syndromes:

- Clinical examination (symptoms and signs)
- Electro-physiologic studies (EMG & Nerve conductive studies)
- US
- MRI

Normal Nerve US appearance:

- **Longitudinal section:**
  - Echogenic linear structure
  - Hypoechoic parallel lines within.
  - Surrounded by echogenic envelope.
  - Little movement on dynamic examination.
- **Transverse section:**
  - Oval or rounded structure.
  - Punctate internal architecture.

Abnormal Nerve US appearance:

- Thickened (diffuse or segmental)
- Hypoechoic
- Loss of normal parallel linear echotexture

MRI Neurography Protocol

Sequence
Axial T1-weighted turbo spin-echo
Axial T2-weighted SPAIR
Coronal proton-density SPAIR
Coronal T1-weighted turbo spin-echo
Coronal 3D STIR SPACE
Sagittal T2-weighted 3D SPACE
Coronal 3D VIBE*

Normal Nerve MRI Appearance:	**Abnormal Nerve MRI Appearance:**
Size: Similar to that of the adjacent artery, gradually decreases distally	Size: Focal or diffuse enlargement, larger than the adjacent artery
T1&T2:Isointense relative to skeletal muscle STIR: isointense to minimally Hyperintense on STIR	T2:Hyperintense (similar to that of adjacent vessels)
3D SPACE: uniform symmetric high signal intensity	3D SPACE: asymmetric areas of hyperintensity
Fascicular Pattern Present on T1- and T2-	Fascicular Pattern: Single or multiple enlarged fascicles, loss of fascicular pattern
Course: Smooth with no focal deviations	Course: Focal or diffuse deviations
Surrounded by hyperintense perineural fat: Clear fat Planes	Perineural fat: Peripheral strand-like areas of Hypointensity on T1- and T2- or nerve encasement
No enhancement, Except in areas with a normally Deficient blood-nerve barrier (eg, dorsal root ganglion)	Enhancement: Present in tumors and infections (seen as disruption of the blood-nerve barrier)

Indirect MRI signs of Nerve Injury

Muscle Denervation Patterns

Appearance of Denervation Changes In Skeletal Muscles at MR Neurography

Duration	Imaging Findings
Acute (<1 month)	Areas of hyperintensity on T2-weighted images (indicative of edema)
Subacute (1–3 months)	Areas of hyperintensity on T2- (indicative of edema) and T1-weighted images (indicative of fatty infiltration)
Chronic (>3 months)	Areas of hyperintensity on T1-weighted images (indicative of fatty infiltration) and reduced muscle volume (indicative of atrophy)

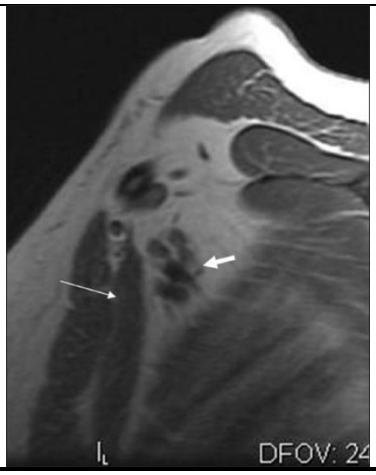
I. Upper Limb Neuropathy

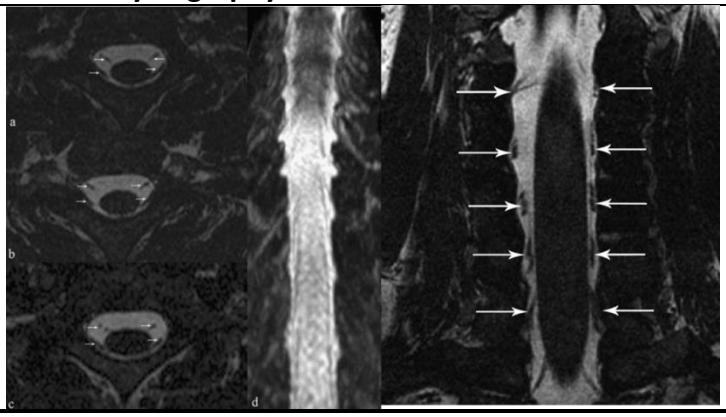
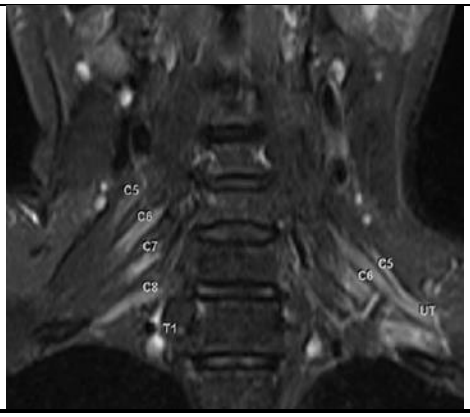
- **Brachial Plexus Entrapment:**
  - ⇨ **Thoracic Outlet Syndrome**
  - ⇨ **Parsonage-Turner syndrome**
- **Supra-Scapular Nerve Entrapment:**
  - ⇨ **Supra-scapular notch Syndrome**
  - ⇨ **Spino-glenoid notch Syndrome**
- **Musculocutaneous Nerve Entrapment**
- **Axillary Nerve Entrapment**
  - ⇨ **Quadrilateral Space Syndrome**
- **Radial Nerve Entrapment**
  - **Proximal Radial Nerve**
  - **Posterior Interosseous Nerve**
    - ⇨ **Radial Tunnel Syndrome**
    - ⇨ **Posterior Inter-osseous Syndrome**
- **Median Nerve Entrapment**
  - ⇨ **Pronator Teres Syndrome**
  - ⇨ **Anterior Interosseous Nerve Syndrome**
  - ⇨ **Carpal Tunnel Syndrome**
- **Ulnar Nerve Entrapment**
  - ⇨ **Cubital Tunnel Syndrome (Elbow)**
  - ⇨ **Guyon canal syndrome (Wrist)**

A- Brachial Plexus Entrapment

1) Thoracic Outlet Syndrome

- Brachial plexus and subclavian artery or vein are vulnerable to entrapment at:
  - **Interscalene space**
  - **Costoclavicular space**
  - **Retropectoralis minor space**

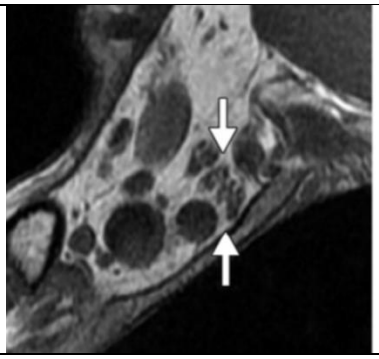
Sagittal T1 **Interscalene Triangle Space**	**Sagittal T1** **Costoclavicular Space**	**Sagittal T1** **Retropectoralis minor space**
Scalene anterior muscle (Thin arrow) Subclavian aretry (Short thick arrow) Roots of brachial plexus (arrow with dashed line)	Space between the clavicle and first rib. Clavicle (Thin arrow) Subclavian artery (thick arrow)	Pectoralis minor muscle (Thin arrow). Subclavian artery (thick arrow) Cords of brachial plexus lie superior to it
		

3D MR Myelography Axial & Coronal	**Coronal STIR**
	

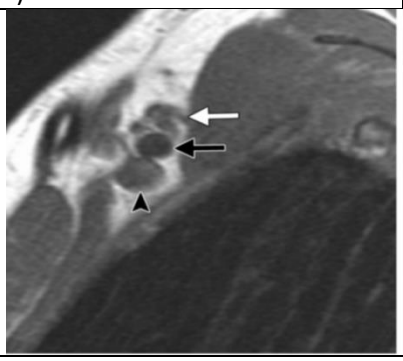
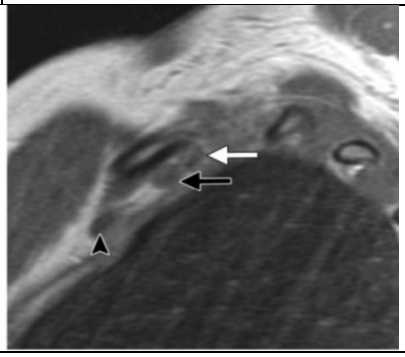
Causes :

- Posttraumatic fibrosis of the scalene muscles
- Compression secondary to activities like backpacking
- Clavicular fractures with abundant callus formation.
- Exercise-related causes presumed secondary to muscle hypertrophy affect weight lifters, swimmers, and athletes involved in “Dominant arm sports” such as tennis.
- Mass lesions such as lipomas, neurogenic tumors,
- Accessory muscles, and fibrous bands.

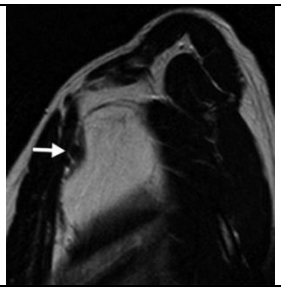
Interscalene Space:

Normal Brachial plexus	ABNORMAL Clumped Brachial Plexus
	

Costoclavicular Space

Arm in the neutral position demonstrates a normal-sized costoclavicular space with fat surrounding the subclavian vessels and brachial plexus (white arrow).	Arm in abduction shows compression of the subclavian vessels and brachial plexus (white arrow).
	

Retropectoralis Minor Space:

Lipoma in retropectoralis minor space => Compression of the axillary vessels and brachial plexus anteriorly	

2) Parsonage-Turner Syndrome

- Acute idiopathic brachial neuritis and neuralgic amyotrophy
- Unknown cause, postulated localized infectious or immunologic disorders, with a possible genetic predisposition
- 3rd to 7th decades of life
- > Males
- symptoms include severe atraumatic shoulder pain followed by significant weakness of one or more shoulder muscles
- At presentation, parsonage-turner syndrome may be confused with rotator cuff tear, labral injury, shoulder impingement, or adhesive capsulitis
- Recovery usually occurs gradually over a period of months, with 90% of patients being symptom free by the end of 3 years
- The longer the initial painful period lasts, the longer the recovery period

❖ ***Multiple Nerves May Be Involved:***

Suprascapular nerve (97%):

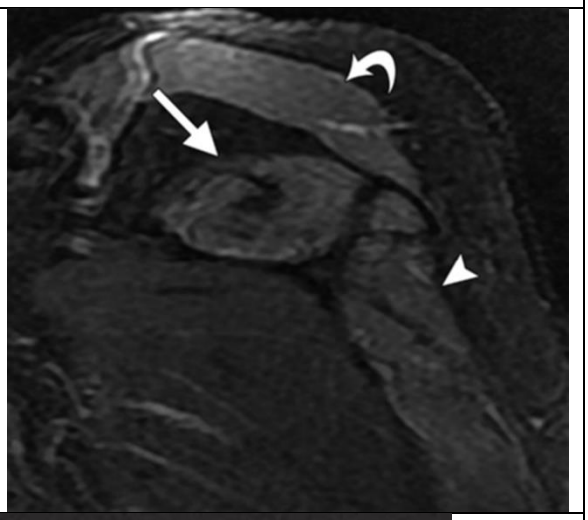
- Supraspinatus muscle
- Infraspinatus muscle

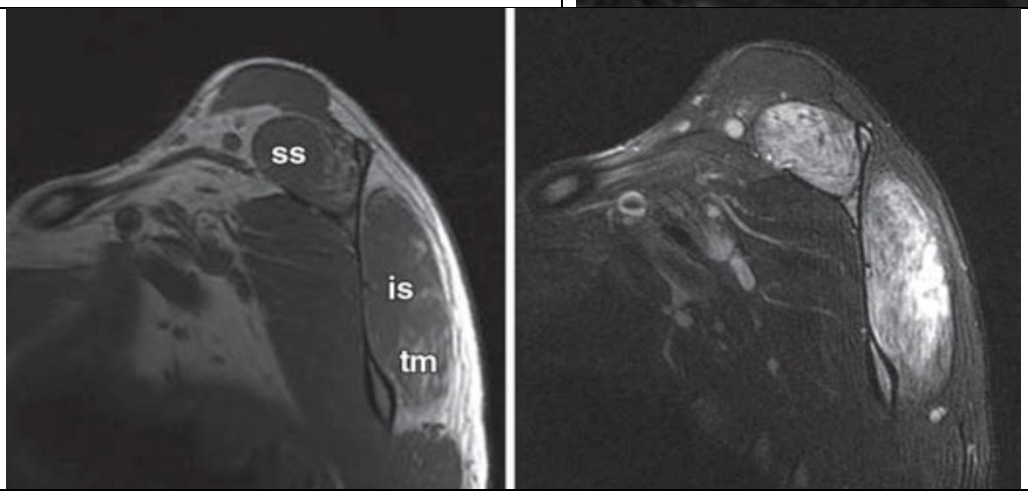
Axillary nerve (50%):

- Deltoid and teres minor muscles

Subscapular nerve (3%):

- Subscapularis muscle.



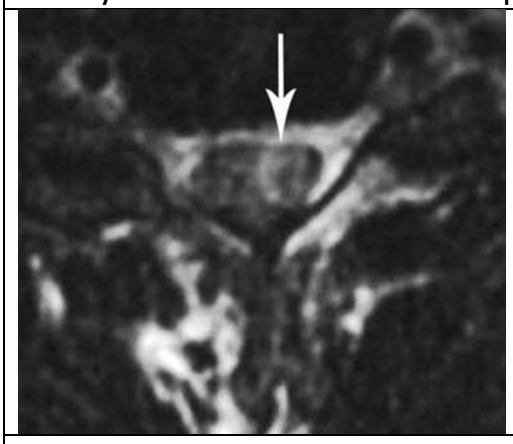
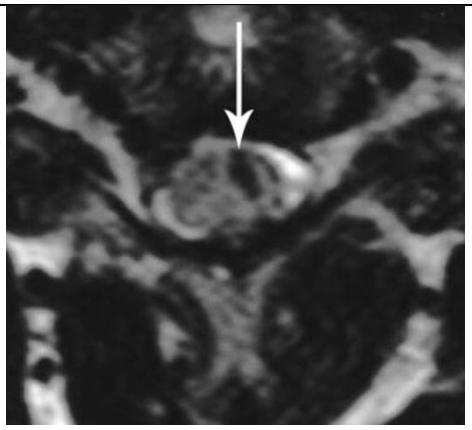


3) Brachial Plexus Injury

The common causes of brachial plexus injuries are:

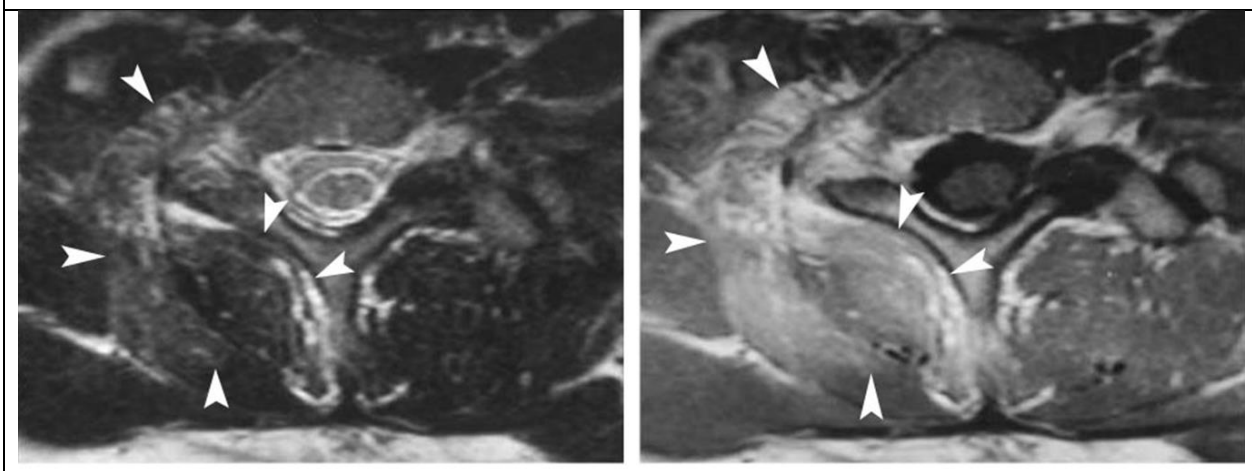
- Road traffic accidents and birth palsy.

❖ Spinal Cord Signal Changes:

Hyperintense areas on T2 WI:	**Hypointense areas on T2 WI:**
• Edema in the acute phase • Myelomalacia in the chronic phase.	• Hemosiderin deposition on account of hemorrhage
	

❖ Para-spinal Muscles Changes:

- Abnormal signal and enhancement of paraspinal muscles is an accurate indirect sign of root avulsion injury.

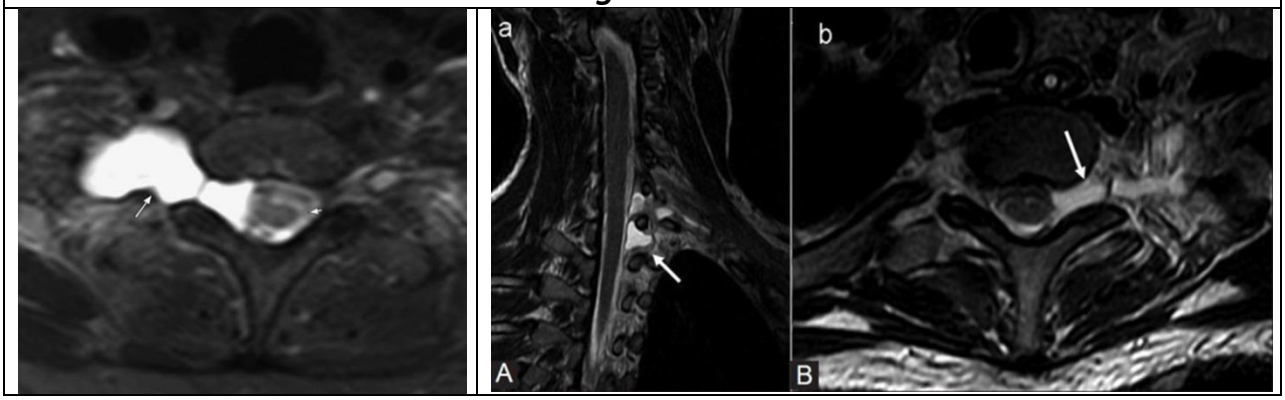


a. b.

❖ Direct Nerve Changes:

- **Nerve Root Avulsion:**
  - Extra-dural Pseudo-meningocele
- **Nerve ruptures**
  - Discontinuity in the neural structures
  - Denervation edema in the muscles
- **Neuropraxic injury:**
  - T2 hyperintense signal in the roots, trunks, or cords
  - with or without enlargement

Nerve Root Avulsion => Pseudomeningocele



B- Musculocutaneous Nerve

- Origin: from the lateral cord of the brachial plexus,
- Motor: supplying the coracobrachialis, brachialis, and biceps brachii muscles.
- Sensory: cutaneous innervation to the lateral forearm.

Course:

- In the arm, it passes between the brachialis and biceps muscles
- Runs lateral to the biceps brachii tendon,
- passes through the antebrachial fascia to enter the subcutaneous tissues.
- then emerges as the lateral antebrachial cutaneous nerve.

Sites of Entrapment.

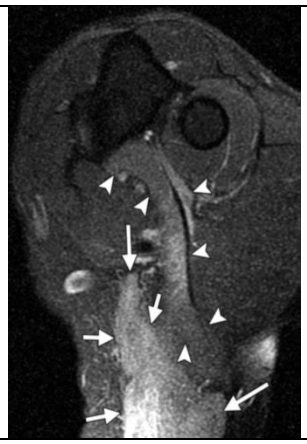
- The coracobrachialis muscle
- The point of emergence of the lateral antebrachial cutaneous nerve.

Causes

- Relatively rare
- Tends to be posttraumatic.
- Proximal to the elbow, the nerve is susceptible to entrapment at or just distal to the coracobrachialis muscle, usually producing weakness of the brachialis and biceps brachii muscles
- The lateral antebrachial cutaneous nerve is vulnerable to entrapment where it pierces the antebrachial fascia in the cubital fossa.
- External compression of the nerve against the biceps brachii tendon, as well as repetitive and vigorous arm exercise, may result in entrapment.

Clinical picture:

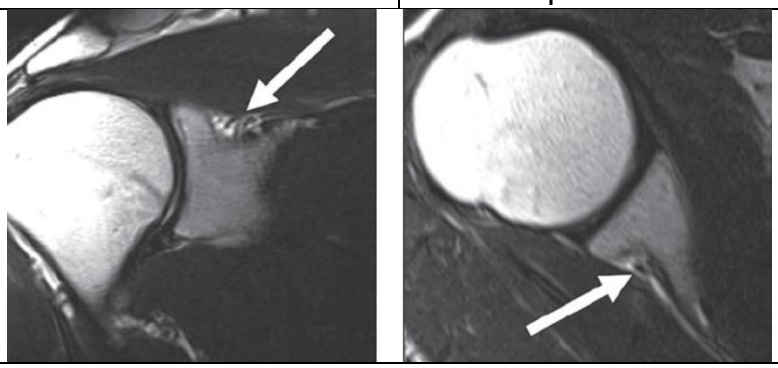
- Weakness involving the muscles it innervates.
- Entrapment at or just distal to the coracobrachialis muscle typically produces symptoms in all the innervated muscles except the coracobrachialis muscle
- Sensory abnormalities mimicking lateral epicondylitis are present in the lateral aspect of the forearm.
- MRI: Edema within
  - ***Coracobrachialis***
  - ***Brachialis***
  - ***Brachioradialis muscles***



C- Supra-Scapular Nerve Entrapment

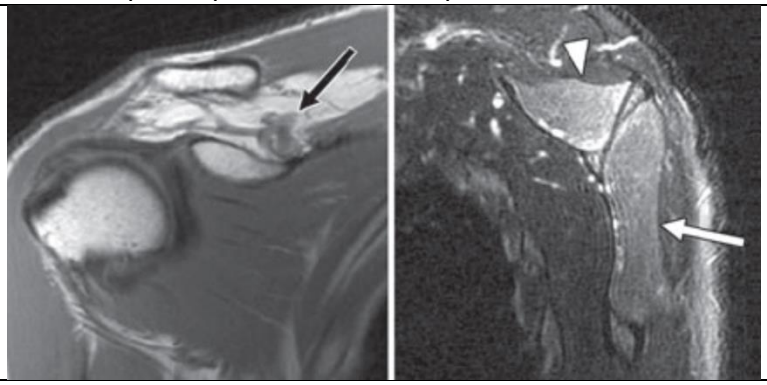
Impingement of the supra-scapular nerve in:

Supra-scapular notch	**Spino-glenoid notch**
⇨ Edema and atrophy of supraspinatus and infraspinatus muscles	⇨ Edema and atrophy of the infraspinatus muscle only



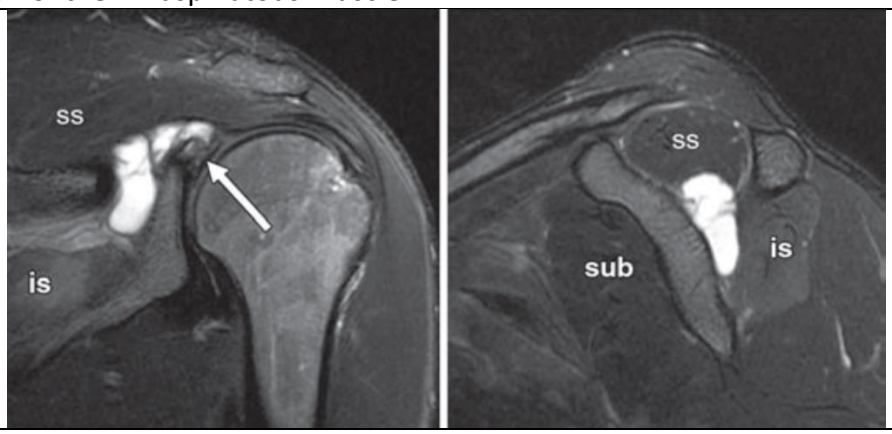
1) Supra-scapular Notch

Varices at the suprascular notch => Compression of the suprascapular nerve
=> Denervation edema of suprascapular and infrascapular muscles.



2) Spino-Glenoid Notch

Para-labral cyst at spino-glenoid notch => Compression of the suprascapular Nerve
=> Denervation of the infraspinatous Muscle

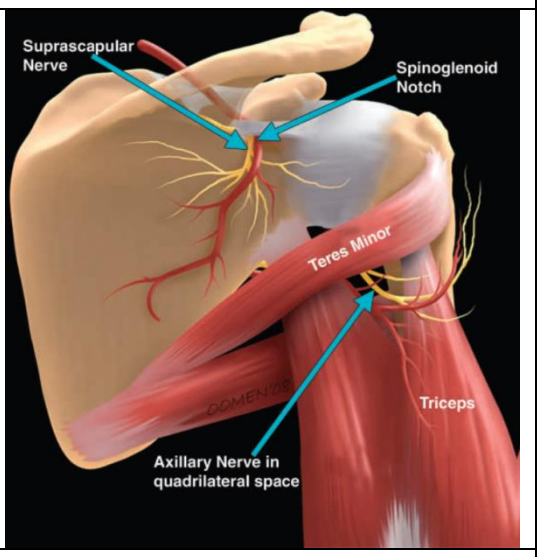


D-Axillary Nerve Entrapment

⇨ Quadrilateral Space Syndrome

Quadrilateral Space bounded by:

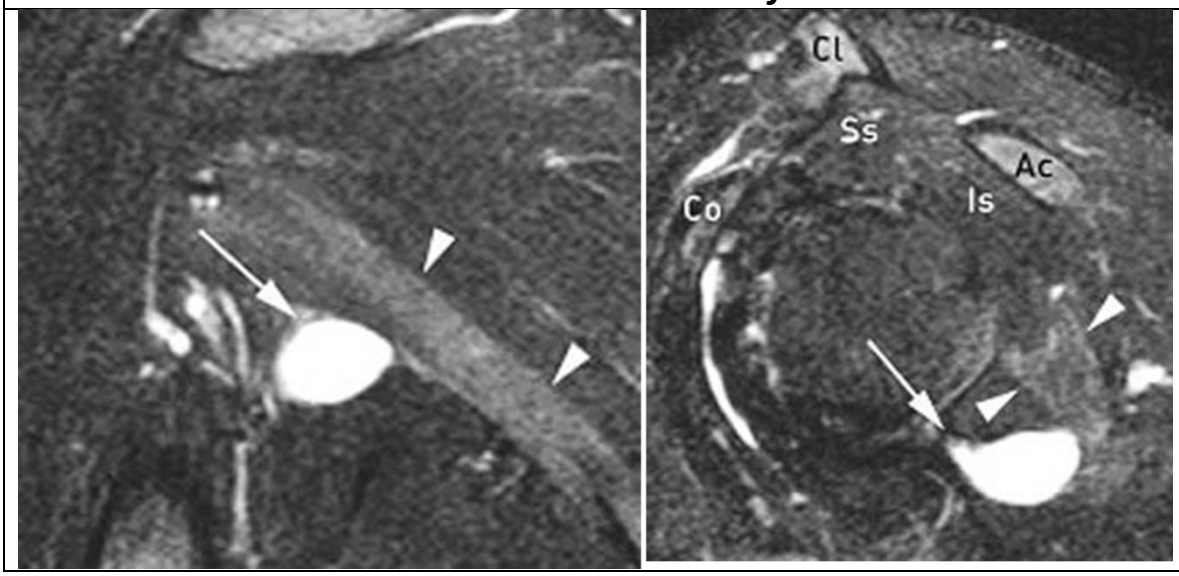
- Laterally by the medial aspect of the humerus
- Medially by the long head of the triceps muscle
- Superiorly by the teres minor muscle
- Inferiorly by the teres major muscle



MRI Imaging:

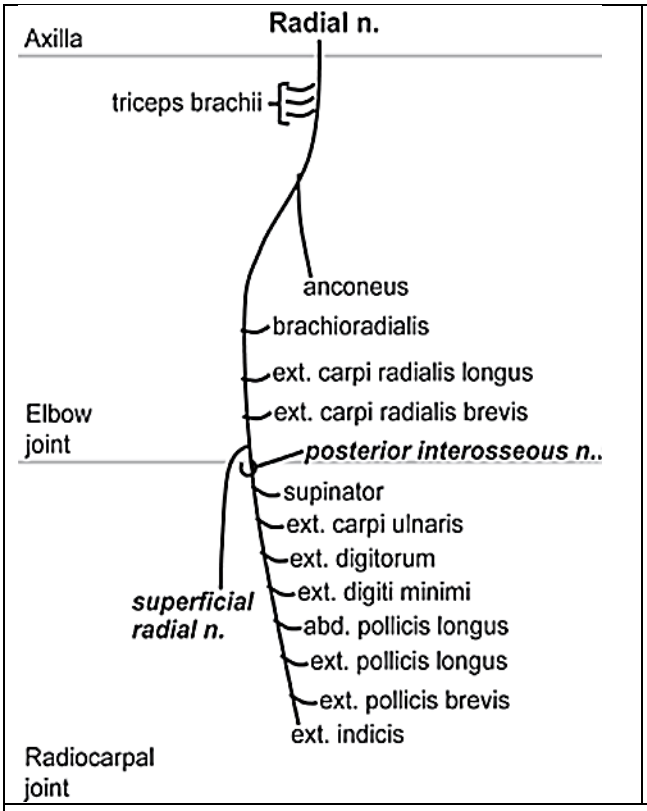
- Edema in the teres minor muscle or, less commonly, the deltoid muscle
- If isolated edema or atrophy of the teres minor or deltoid muscle is detected in the absence of a quadrilateral space mass, signs of glenohumeral instability should be sought

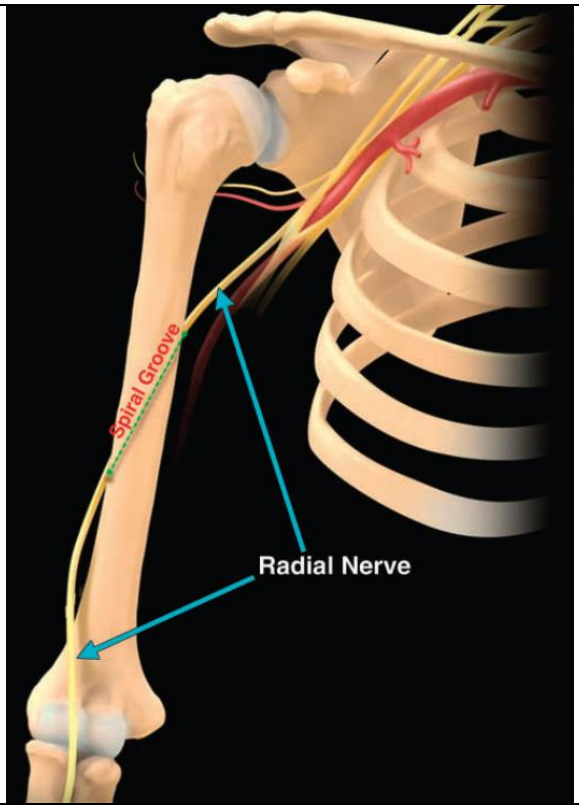
Paralabral cyst in quadrilateral space => Compression of the axillary vessels and nerve => Denervation edema of teres minor



E- Radial Nerve Entrapment

1) Proximal Radial Nerve Entrapment





- Saturday night palsy = classic radial neuropathy secondary to intoxication, whereby sleeping with the arm draped over a chair causes direct pressure on the radial nerve
- Fracture of the humeral shaft => Nerve injury within the spiral groove
- Entrapment neuropathy can also be caused by a fibrous arch of the lateral head of the triceps muscle in weight lifters

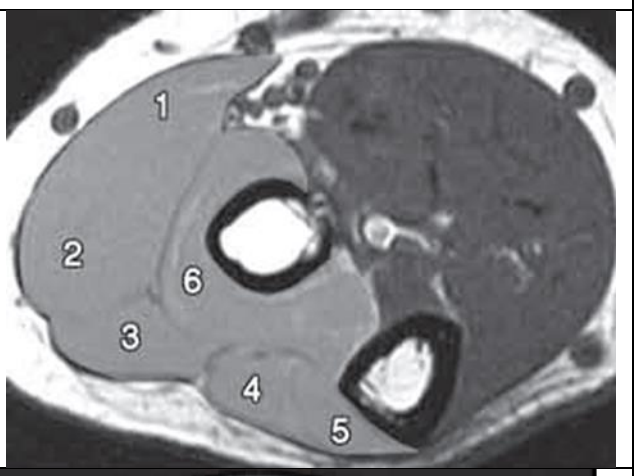
Clinical Picture:

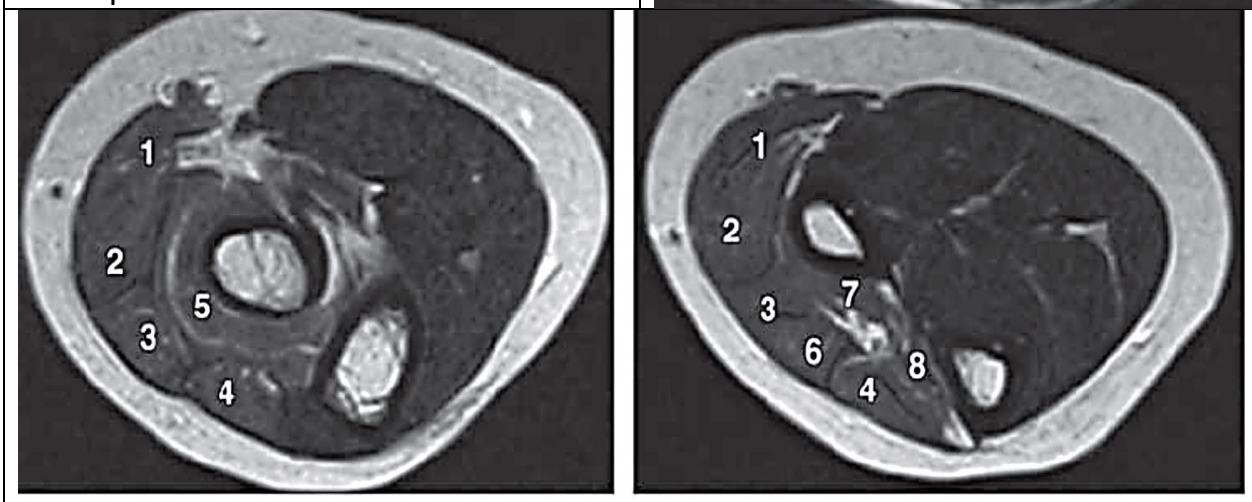
- Functional loss of accessory forearm supination and elbow flexion.
- Wrist drop
- Finger drop
- Sensory loss in the dorsolateral hand.
- Elbow extension is spared because the branches to the triceps muscle come off proximal to the spiral groove, helping distinguish this neuropathy from a higher level of compression

Muscles involved:

1 = Brachioradialis
2 = Extensor Carpi Radialis Longus And Extensor Carpi Radialis Brevis

+ muscles innervated by the posterior interosseous nerve
3 = Extensor Digitorum
4 = Extensor Carpi Ulnaris
5 = Anconeus,
6 = Supinator.





a. b.

Figure 8. Proximal radial nerve denervation pattern in a 24-year-old woman with right wrist weakness. Axial T2-weighted MR images (3219/88) of the proximal part of the right forearm (**b** obtained distal to **a**) show increased signal intensity of the muscles in the radial nerve territory. *1* = brachioradialis, *2* = extensor carpi radialis longus and brevis, *3* = extensor digitorum, *4* = extensor carpi ulnaris, *5* = supinator, *6* = extensor digiti minimi, *7* = abductor pollicis longus, *8* = extensor pollicis longus.

2) Posterior Interosseous Nerve (PIN) Entrapment

Site of entrapment of radial nerve in the radial tunnel:

- Fibrous bands of the anterior capsule of the radiocapitellar joint at the entrance to the tunnel
- Radial tunnel = 5-cm long tunnel bounded by the brachialis and brachioradialis muscles
- Leash of Henry = radial recurrent artery
- Arcade of Frohse = (fibrous arch at the proximal supinator muscle)

2 Clinical Syndromes:

- **Radial Tunnel Syndrome:**
  - Painful condition + No/Mild motor weakness
- **PIN syndrome:**
  - Painless condition
  - Pure motor weakness without significant sensory affection.

Clinical Picture of PIN Syndrome:

- ***Radial Deviation of the hand due to:***
  - Sparring of the extensor carpi radialis longus and brevis
  - Weakness of the extensor carpi Ulnaris

Muscles involved in PIN syndrome supplied by PIN:

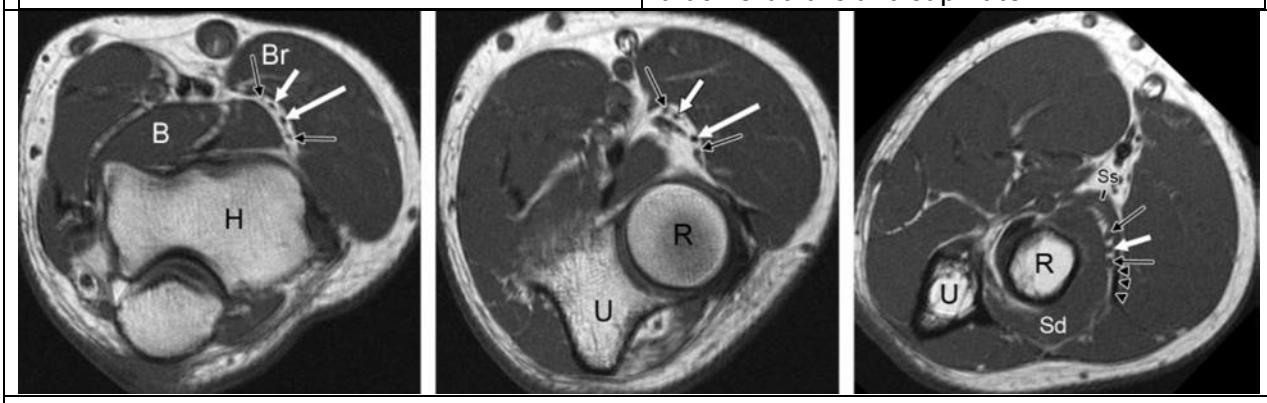
- Extensor carpi ulnaris
- Extensor digitorum
- Extensor digiti minimi
- Abductor pollicis longus
- Extensor pollicis longus
- Extensor pollicis brevis
- Extensor indicis
- ± Supinator

Sparring 3 muscles:

- Brachioradialis
- Extensor carpi radialis longus
- Extensor carpi radialis brevis

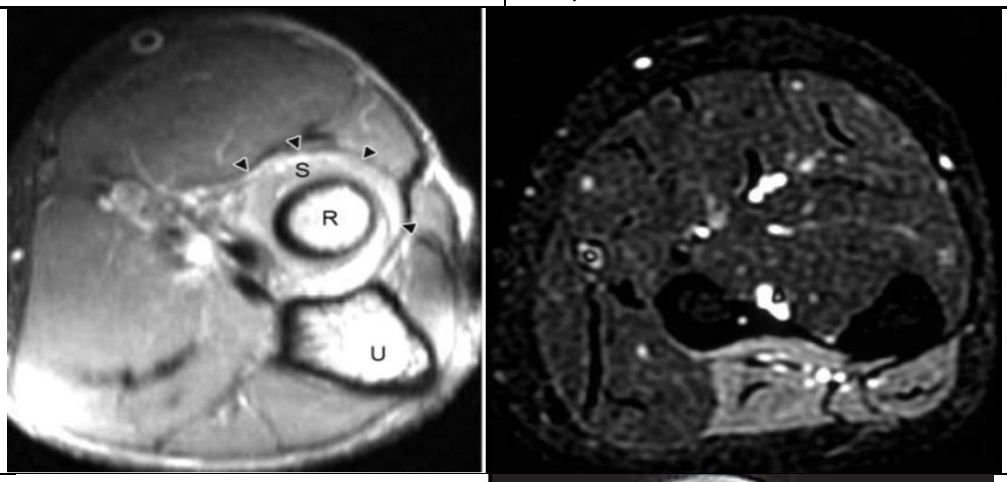
Normal PIN

Radial Nerve at elbow joint divides into superficial radial nerve and posterior interosseous nerve between Brachioradialis and Brachialis	Posterior Interosseous Nerve Between Superficial and deep heads of supinator Muscle. Superficial radial nerve between brachioradialis and supinator



PIN Syndrome

Supinator muscle edema	Edema of ECRL, ECRB, ECU, ED, EDM, EPL, APL



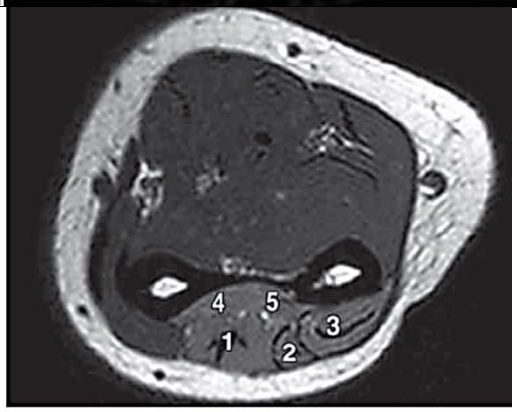
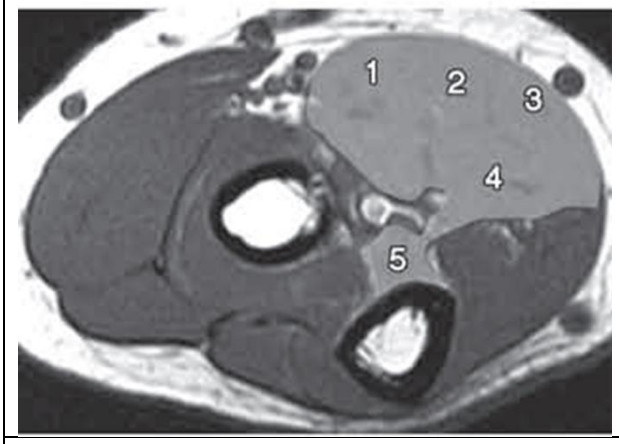


Figure 9. Posterior interosseous nerve denervation pattern in a 27-year-old woman with posterior interosseous nerve syndrome. Axial T2-weighted MR image (2981/100) of the right forearm shows hyperintensity of extensor muscles. *1* = extensor digitorum, *2* = extensor digiti minimi, *3* = extensor carpi ulnaris, *4* = abductor pollicis longus, *5* = extensor pollicis longus.

F- Median Nerve Entrapment

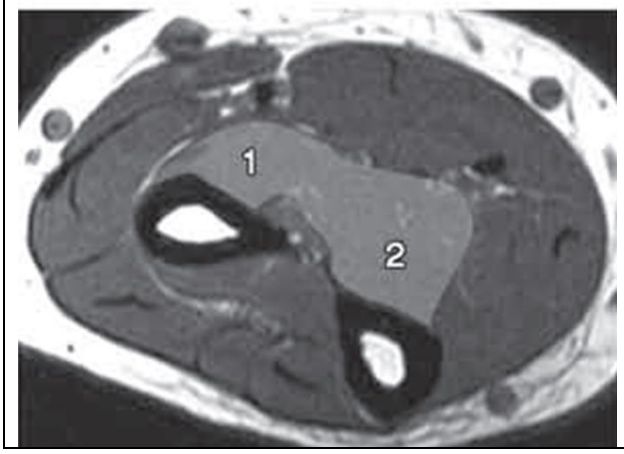
Median nerve

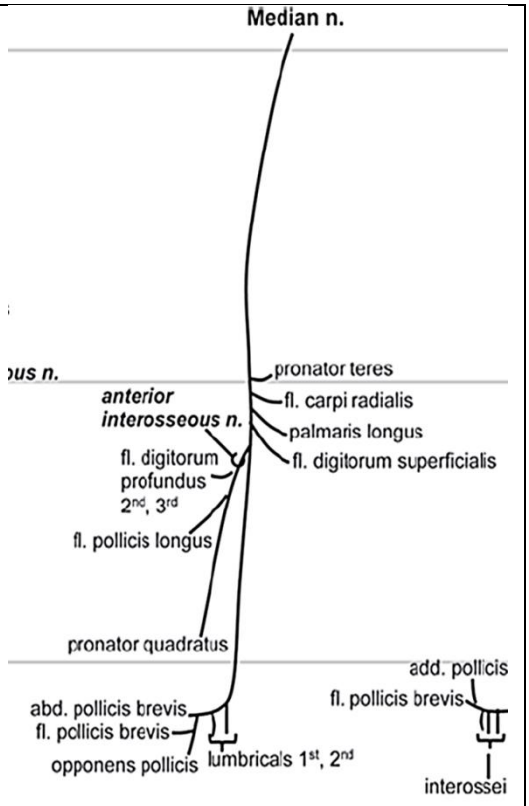
1 = Pronator Teres
2 = Flexor Carpi Radialis
3 = Palmaris Longus
4 = Flexor Digitorum Superficialis
5 = Radial Part Of Flexor Digitorum Profundus.



Anterior interosseous nerve

1 = flexor pollicis longus
2 = radial part of flexor digitorum profundus.





1) Pronator Teres Syndrome

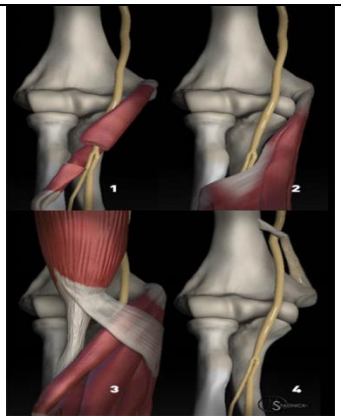
- PTS a is rare entrapment syndrome
- Most common in women past 40.
- Compression of the median nerve near the elbow; between the humeral and ulnar heads of the pronator teres muscle

Clinical Picture

- **Sensory**: pain in the distribution of the median nerve (volar forearm and the radial three digits and radial aspect of the fourth digit)
- **Motor:** Inability to oppose the thumb

Causes:

1) Elbow joint between the superficial and deep heads of the pronator teres muscle (the most common cause of median nerve compression)
2) Proximal forearm by a thickened proximal edge of the flexor digitorum superficialis muscle
3) Proximal elbow by a thickened biceps aponeurosis
4) Distal humerus by the ligament of Struthers



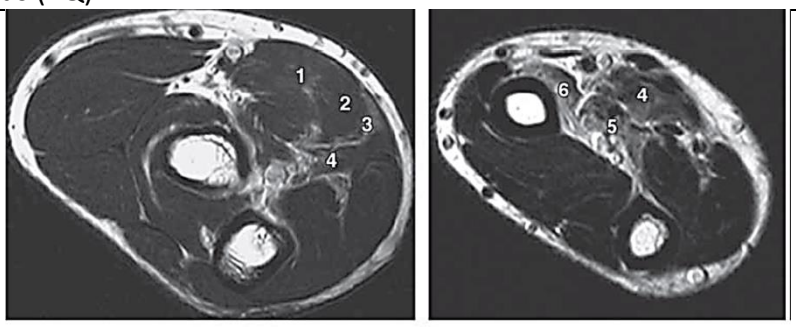
Muscle Distribution:

Pronator-flexor muscle group of the forearm:

Pronator teres (PT),
Flexor carpi radialis (FCR),
Flexor digitorum superficialis (FDS)
Palmaris longus (PL)

+ Muscles supplied by anterior interosseous nerve:

Flexor pollicis longus (FPL),
Radial part (2nd and 3rd digit) of the flexor digitorum profundus (FDP)
Pronator quadratus (PQ)



a. b.

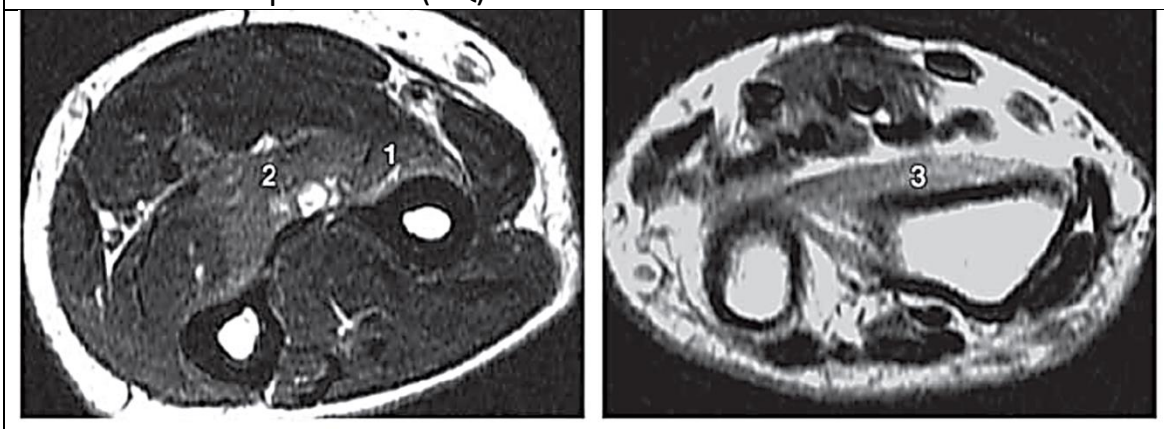
Figure 10. Proximal median nerve denervation pattern in a 51-year-old man with pronator teres syndrome. Axial T2-weighted MR images (2287/80) obtained at proximal (a) and distal (b) levels of the right forearm show abnormal hyperintensity of the muscles in the median nerve territory. *1* = pronator teres, *2* = flexor carpi radialis, *3* = palmaris longus, *4* = flexor digitorum superficialis, *5* = flexor digitorum profundus, *6* = flexor pollicis longus.

2) Anterior Interosseous Nerve Syndrome = Kiloh-Nevin Syndrome

- Pure motor neuropathy
- Pronation weakness that is due to weakness of the pronator quadratus muscle and
- Pinching deformity = Patients fail to make an "O.K."sign: due to weakness of flexion of the interphalangeal joint of the thumb and the distal interphalangeal joint of the index finger
- No sensory loss because the anterior interosseous nerve is purely a motor nerve, patients with complete nerve palsy have

Muscle Distribution:

- Flexor pollicis longus (FPL)
- Radial part (2nd and 3rd digit) of the flexor digitorum profundus (FDP)
- Pronator quadratus (PQ)



a. b.

Figure 11. Anterior interosseous nerve denervation pattern in a 57-year-old man with anterior interosseous nerve syndrome. Axial T2-weighted MR images (3317/83) obtained at mid **(a)** and distal **(b)** levels of the right forearm show abnormal hyperintensity in the flexor pollicis longus *(1)*, the radial part of the flexor digitorum profundus *(2)*, and the pronator quadratus *(3)*.

3) Carpal Tunnel Syndrome

- Compression of the median nerve at the wrist.
- The most common entrapment neuropathy in the upper limb

The carpal tunnel is formed by

The transverse carpal ligament
The volar surface of the carpal bones.
The median nerve lies immediately deep to the transverse carpal ligament.

Clinical Picture:

Sensory: paresthesia of the thumb and radial aspect of the ring finger.
Motor: atrophy of the thenar and loss of abduction and opposition of the thumb.

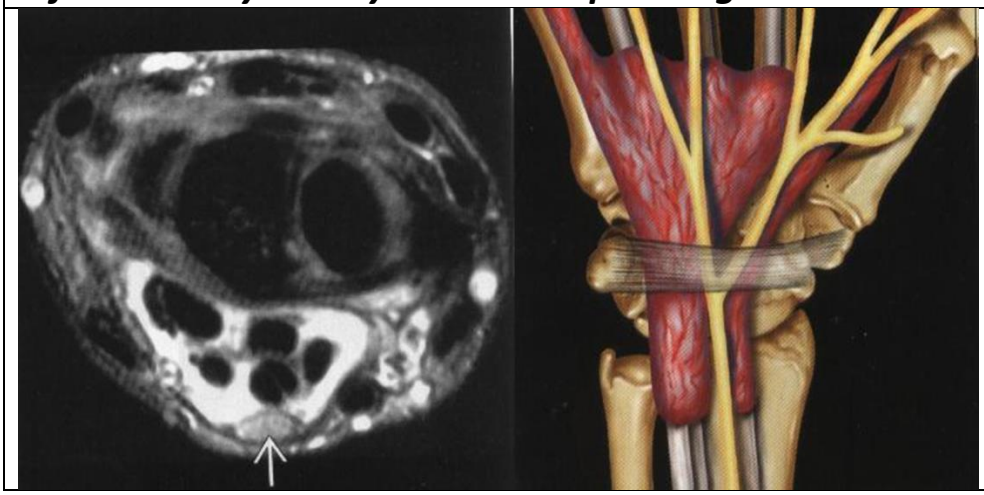
Normal Median Nerve at axial image:

- Median nerve is rounded or ovoid structure
- Intermediate signal on T1 and T2.
- It is flattened at the level of pisiform

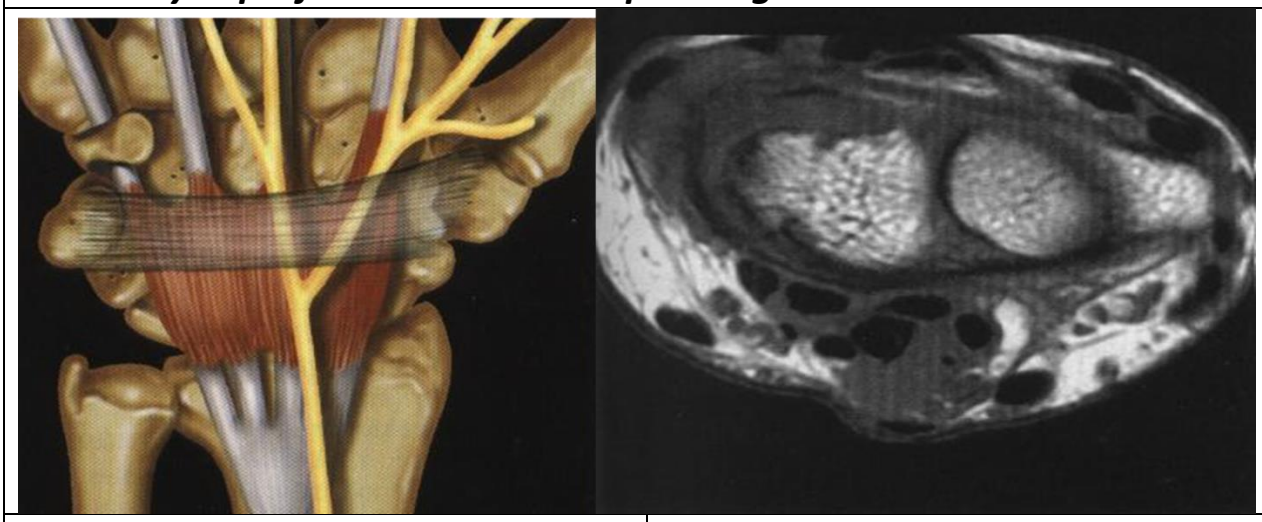
Abnormal Median Nerve at axial image:

- Swollen nerve at the level of pisiform or flattened at the level of hamate.
- Increased T2 FS/STIR signal of the nerve.
- Palmar bowing of the flexor retinaculum at the level of hamate (>2 mm beyond a line connecting the pisiform and the scaphoid).
- Abnormal signal of the thenar muscles

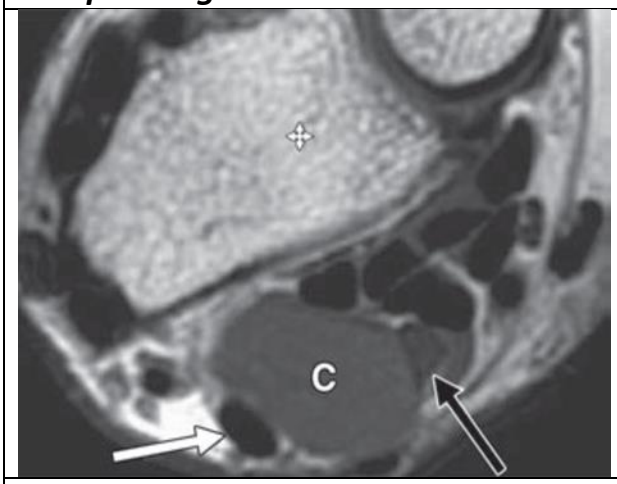
Inflammatory tenosynovitis compressing the median nerve



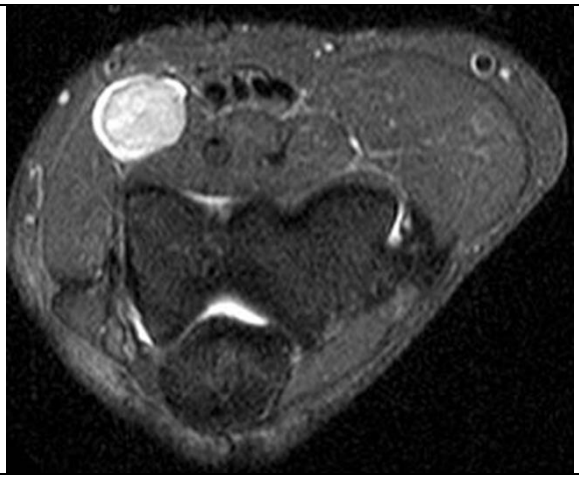
Accessory superficialis muscle compressing the median nerve



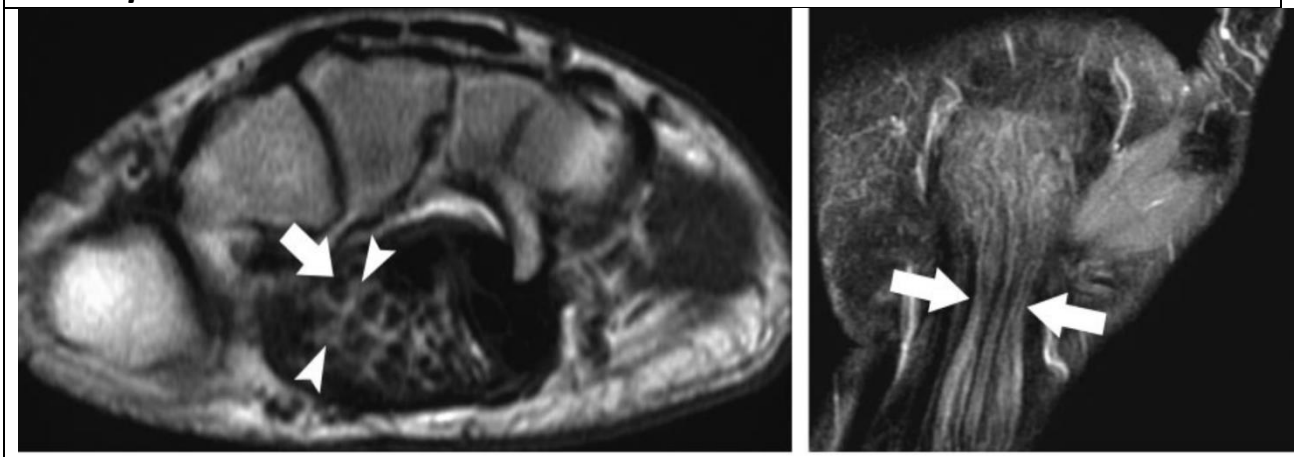
Large ganglion Cyst => Compressing Median Nerve



Median Nerve Schwannoma

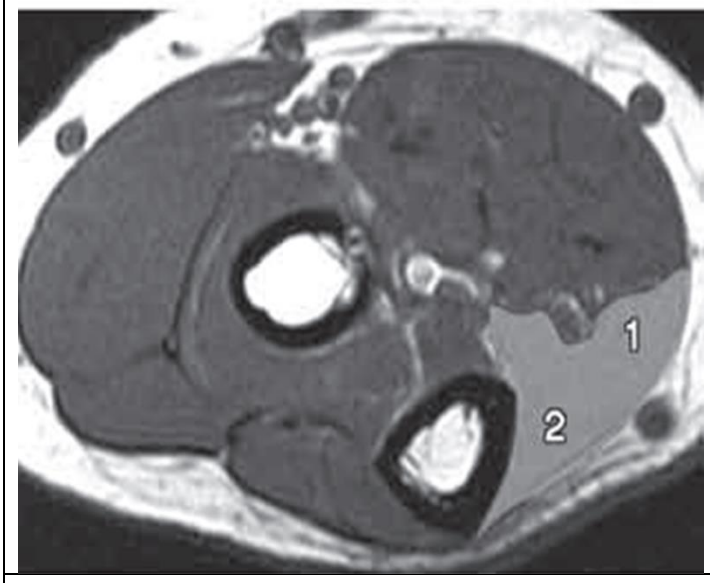


Fibrolipomatous Median Nerve

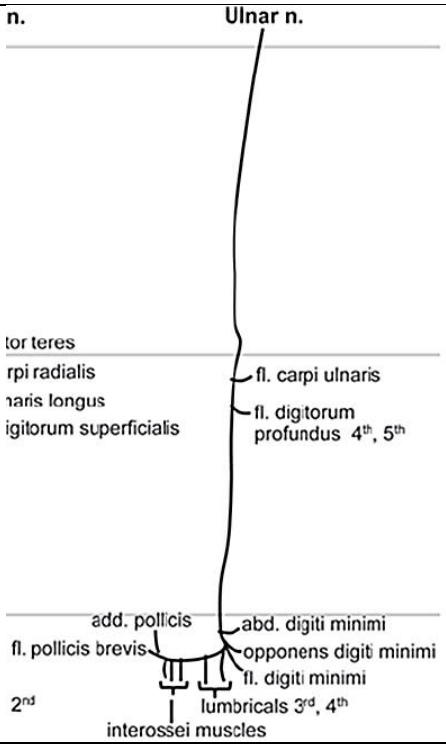


a. b.

G-Ulnar Nerve Entrapment



1 = flexor carpi ulnaris,
2 = ulnar part of the flexor digitorum profundus.

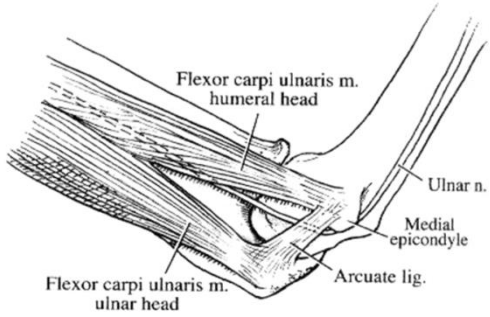


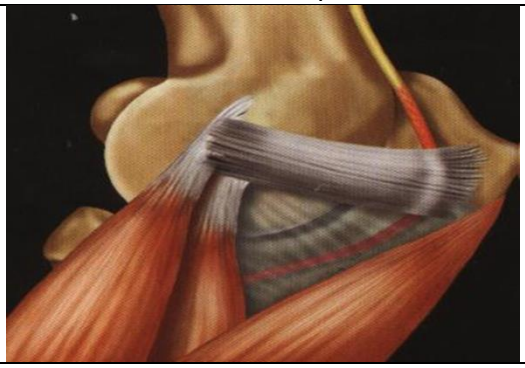
1) Cubital Tunnel Syndrome

- Compression of the ulnar nerve within the cubital tunnel at the level of elbow.
- ***2nd most common*** entrapment neuropathy of upper extremity.

❖ *Cubital Tunnel At the elbow:*

- The ulnar nerve runs posterior to the medial epicondyle in a bony sulcus covered by the arcuate ligament of Osbrn.
- Then it passes between the humeral and ulnar heads of the flexor carpi ulnaris muscle



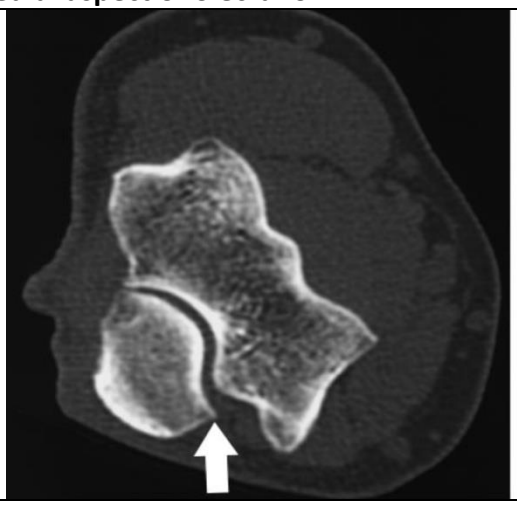
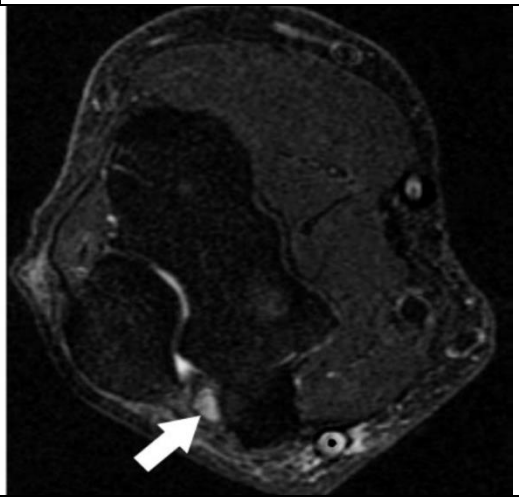
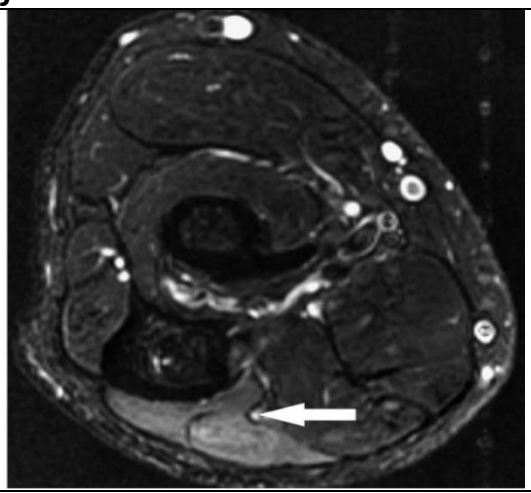


Causes:

- **Dynamic compression:**
  - Recurrent traction as in boxers and baseball pitchers.
- **Anatomic variant:**
  - Replaced arcuate ligament by anconeus epitrochlearis.

Clinical Picture:

- **Sensory:**
  - Paresthesia in small and medial ring finger + Ulnar aspect of palm
- **Motor**
  - Claw-like hand deformity

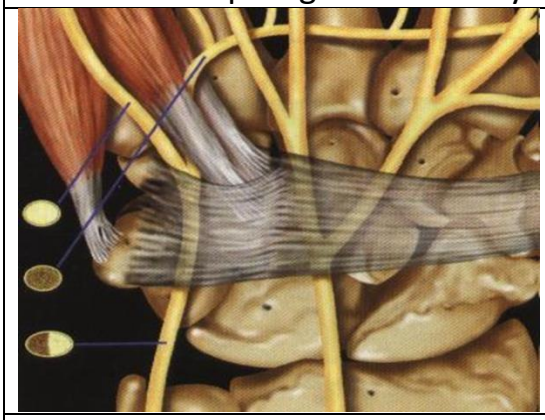
Compression of ulnar nerve by Osteophyte from medial aspect of olecranon	**Ulnar neuritis**
	
Edema denervation of FCU + ulnar half of FDP	
	

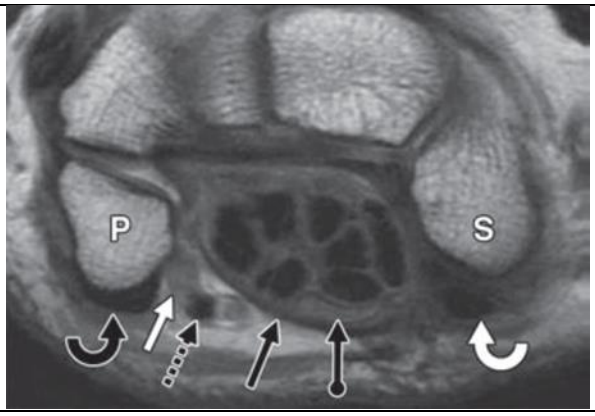
2) Guyon Canal Syndrome

❖ ***Ulnar Tunnel Syndrome = Guyon Canal Syndrome***

A fibro-osseous canal (curved white arrow) formed by:

- Pisiform bone medially
- Flexor retinaculum dorsally
- Palmar carpal ligament vollary.

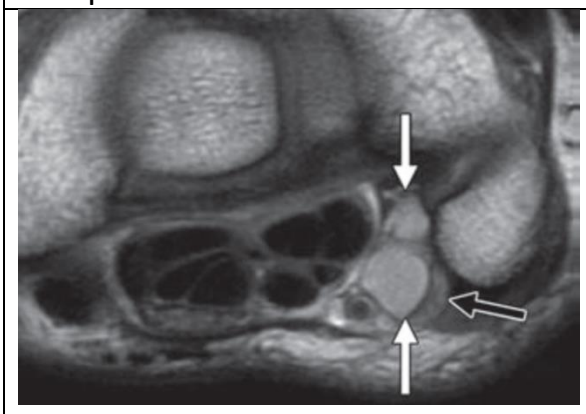




Clinical Picture:

- Pain and tingling along hypothenar and ulnar aspect of 4th and 5th fingers
- Weakness of the hypothenar muscles.

Ganglion cyst in Guyon Canal => Compression of the ulnar nerve



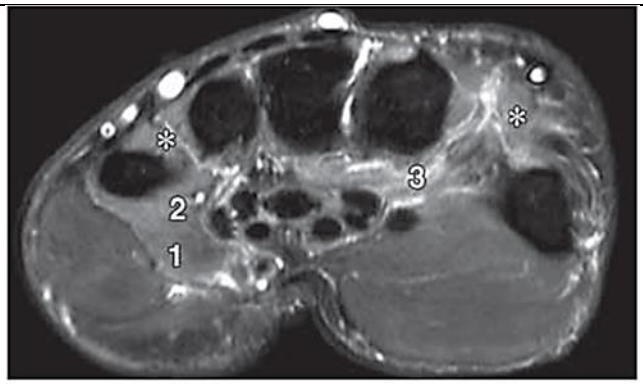
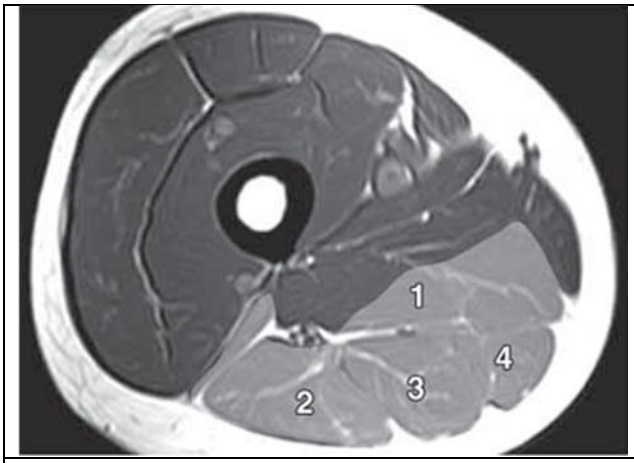


Figure 14. Distal ulnar nerve denervation pattern in a 49-year-old man with Guyon canal syndrome. Axial STIR MR image (4528/30) of the left hand shows abnormal hyperintensity of the muscles innervated by the distal ulnar nerve. *1* = flexor digiti minimi, *2* = opponens digiti minimi, *3* = adductor pollicis, * = interosseous muscles.

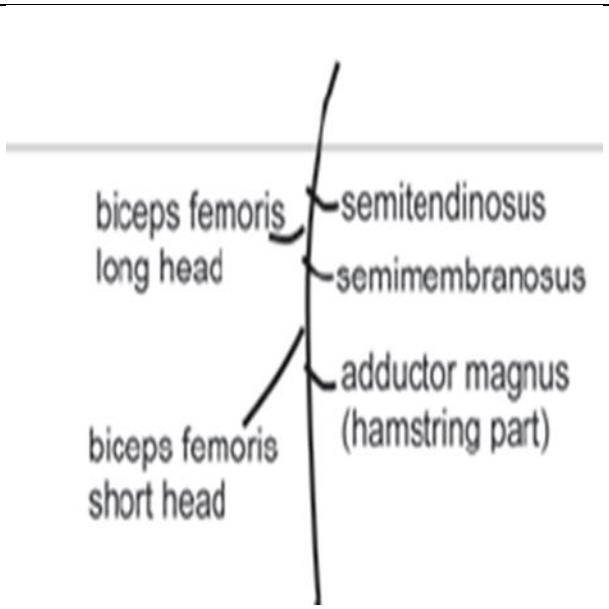
II. Lower Limb Neuropathy

- **Sciatic Nerve:**
  - **Herniated Disk**
  - **Piriformis Muscle Syndrome**
  - **Obturator Internus Muscle SyndromeFemoral Nerve**
- **Obturator Nerve**
- **Superior Gluteal Nerve**
- **Inferior Gluteal Nerve**
- **Femoral Nerve**
- **Peroneal Nerve:**
  - **Peroneal Tunnel**
- **Tibial Nerve:**
  - ⇨ **Proximal Tibial Neuropathy**
  - ⇨ **Tarsal Tunnel Syndrome**
  - ⇨ **Medial plantar neuropathy**
  - ⇨ **Lateral plantar neuropathy**
  - ⇨ **Interdigital neuropathy (Morton neuroma)**
  - ⇨ **Medial plantar proper digital neuropathy (Joplin neuroma)**
- **Sural Nerve**

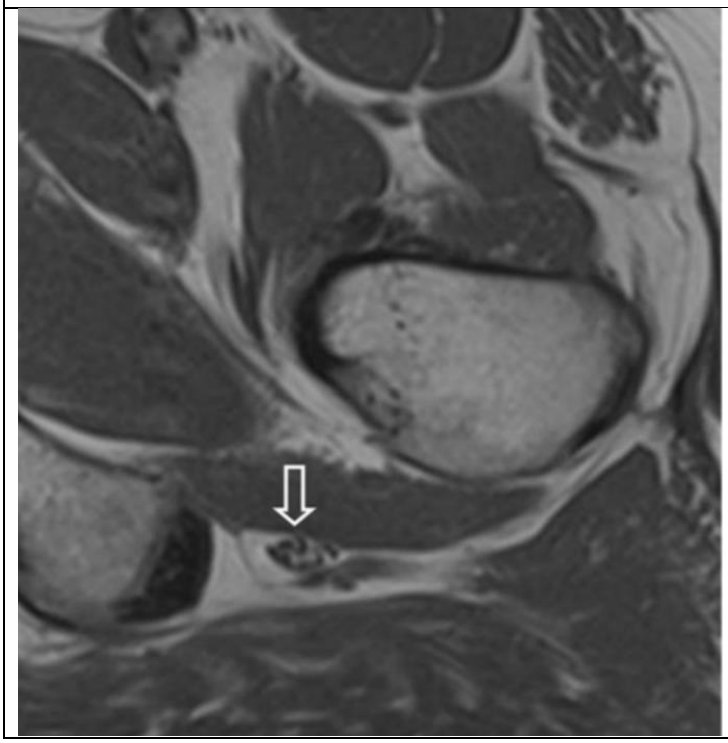
A- Sciatic Nerve

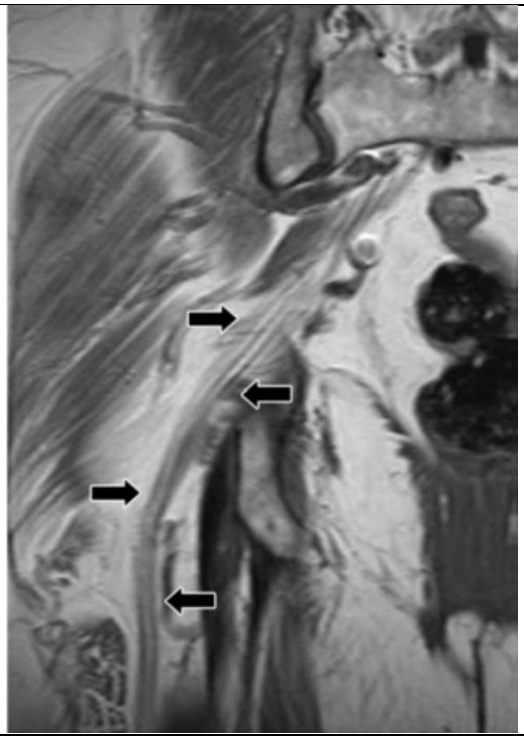


1 = Hamstring Part Of Adductor Magnus
2 = Biceps Femoris
3 = Semitendinosus
4 = Semimembranosus



❖ ***Normal Sciatic Nerve***





❖*Sciatic Neuropathy*

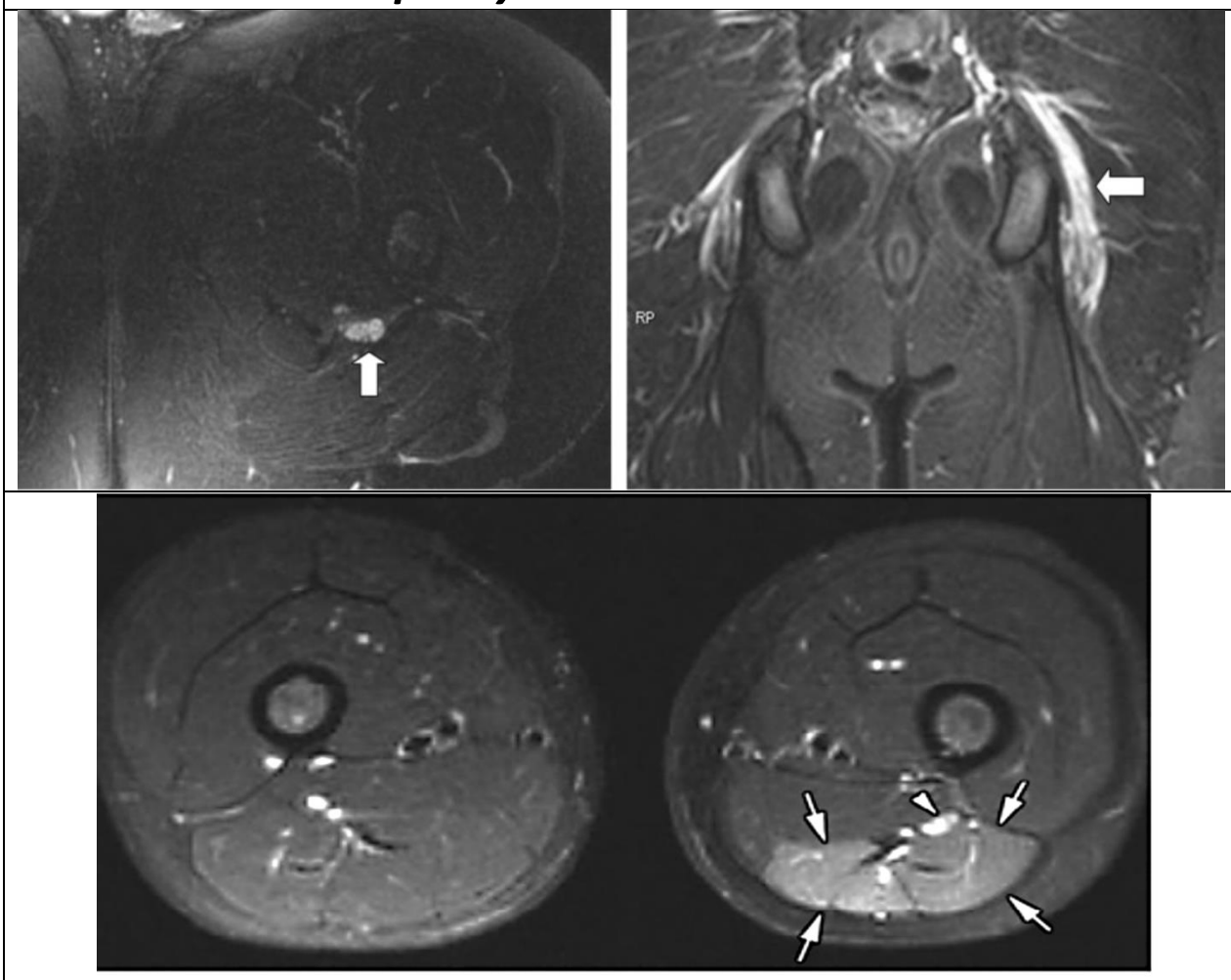


Figure 20. Sciatic neuropathy after total hip replacement. Axial fat-suppressed T2-weighted MR image (3500/50) shows early denervation-related signal intensity changes in the left hamstring muscles (arrows). Note the increased signal intensity of the sciatic nerve (arrowhead).

⇨Piriformis Syndrome (Wallet Sciatica)

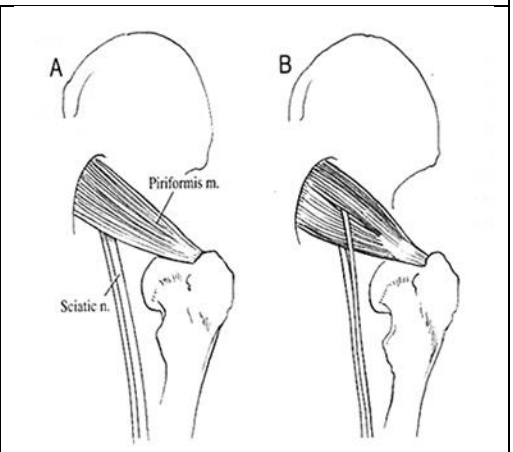
- Neuritis of proximal sciatic nerve secondary to compression or irritation by the piriformis muscle.

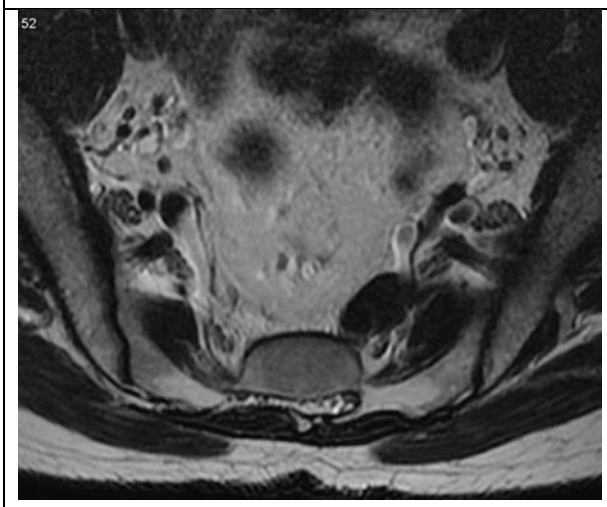
Piriformis Muscle:

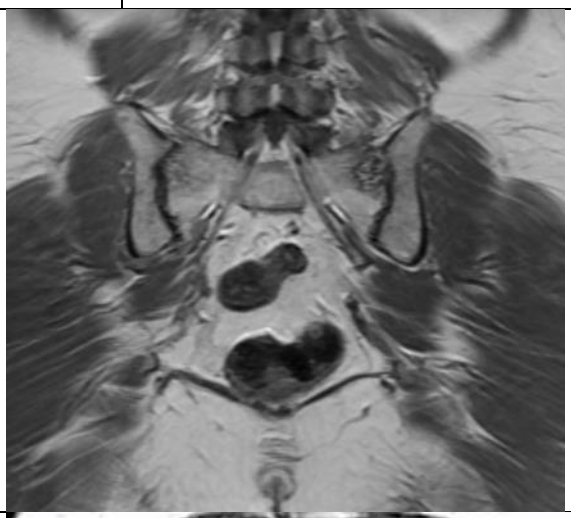
- The muscle arise from the anterior surface of the sacrum and gluteal surface of the ilium
- Crosses the greater sciatic foramen
- Insert into the greater trochanter.

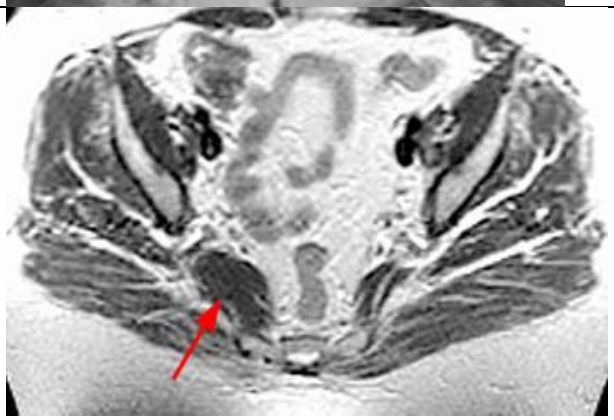
Sciatic Nerve:

- The sciatic nerve passes along the anterior surface of the muscle.
- In some individuals part of the nerve may pass within the muscle.



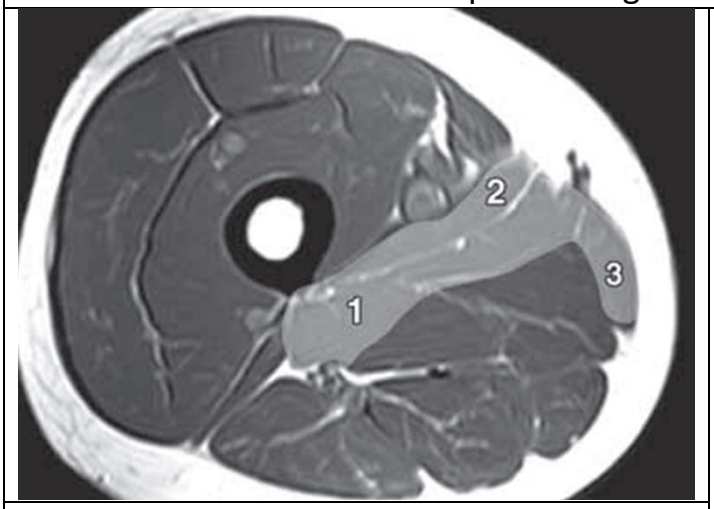




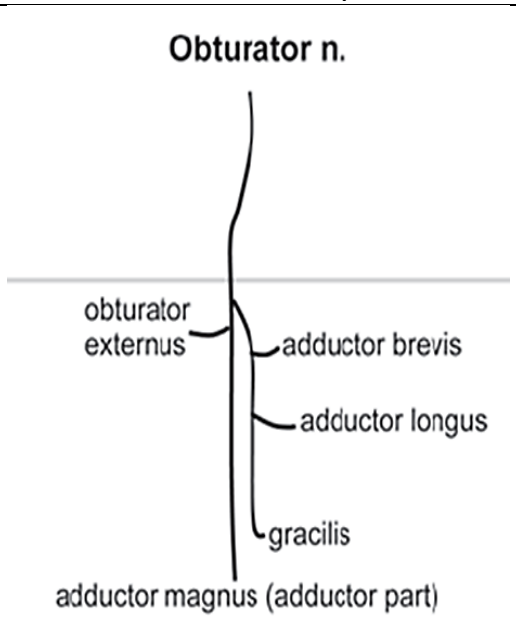


B-Obturator Nerve

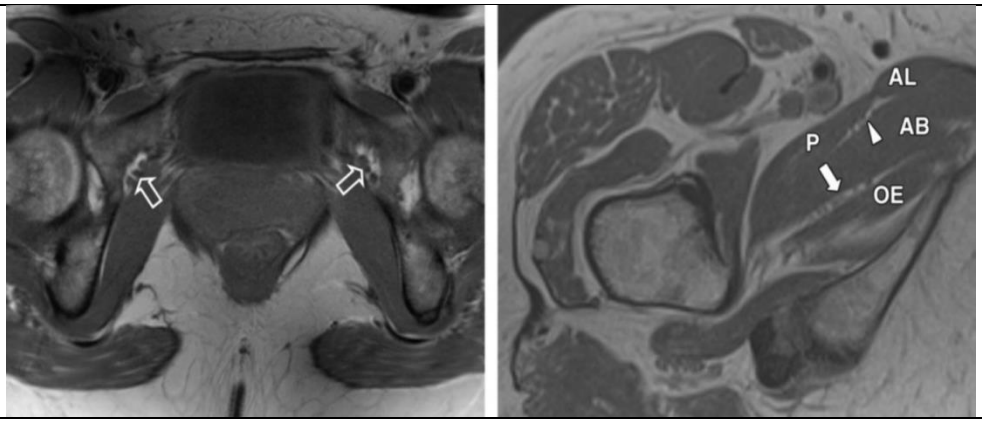
- uncommon because of the deep location of the obturator nerve in the pelvis.
- as it crosses the upper margin of the obturator internus muscle, the obturator nerve is vulnerable to compression against the lateral wall of the pelvis



1 = Adductor part of adductor magnus
2 = Adductor longus
3 = Gracilis.



❖ *Normal Obturator Nerve in Obturator Canal*



Causes:

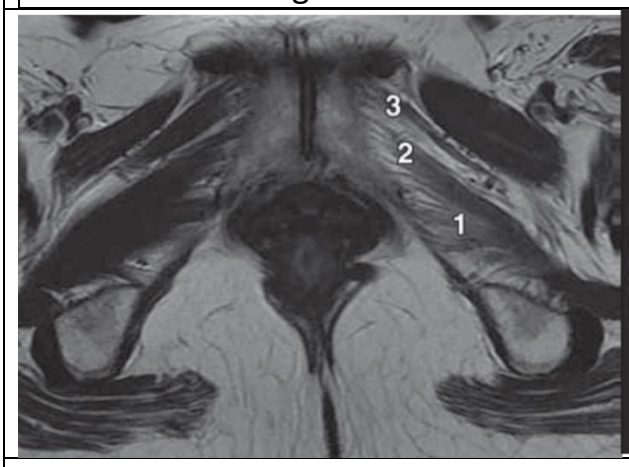
- Pelvic fracture
- Hip arthroplasty
- Abdominal or pelvic surgery
- Pelvic hemorrhage
- Pelvic tumor compression

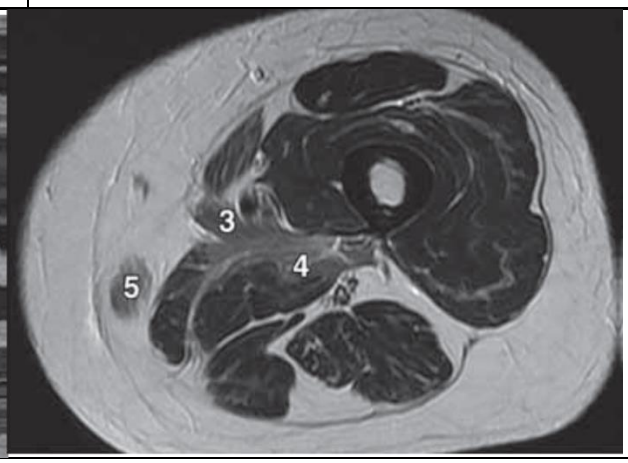
Clinical Picture:

- **Sensory:** alteration and a groin pain in the medial thigh.
- **Motor:** Loss of adduction and internal rotation of the thigh

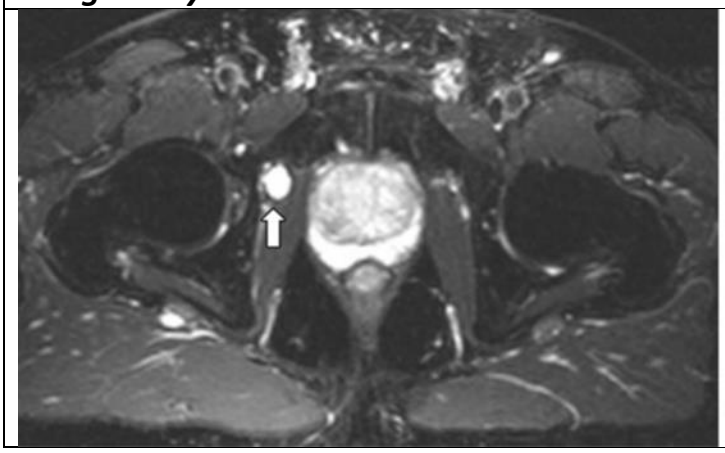
Muscles Distribution:

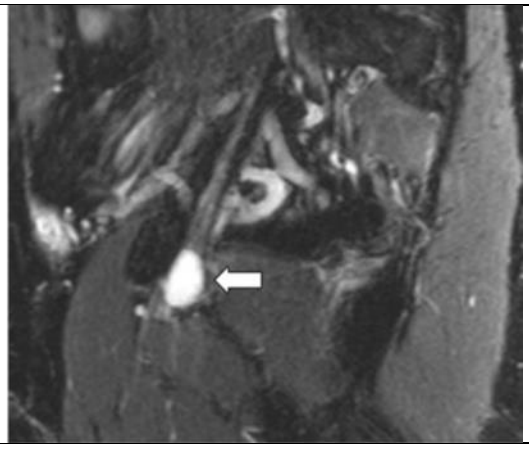
1 = Obturator Externus 2 = Adductor Brevis 3 = Adductor Longus	3 = Adductor longus 4 = Adductor part of adductor magnus 5 = Gracilis





Ganglion Cyst in Obturator Canal

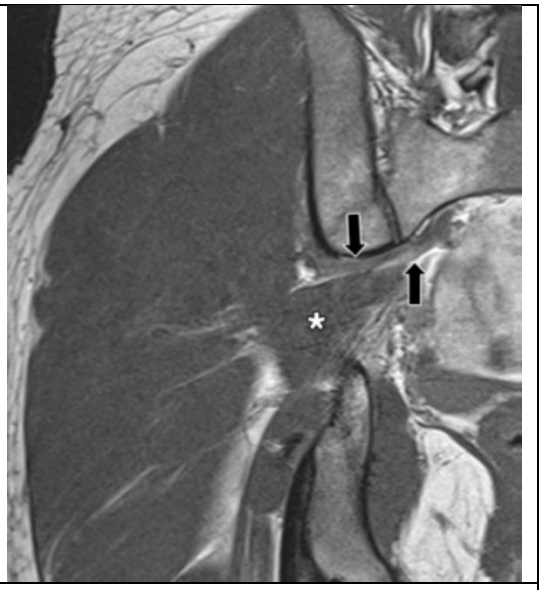




C-Superior Gluteal Neuropathy

Normal Superior Gluteal Nerve In Greater Sciatic Foramen

- It exits the pelvis and curves under the roof of the greater sciatic foramen,
- just above the piriformis muscle
- Between the gluteus medius and minimus muscles.
- The superior branch ascends, then terminates in the gluteus minimus muscle.
- The inferior branch gives rise to branches to the gluteus medius and minimus and ends in the tensor fasciae latae.



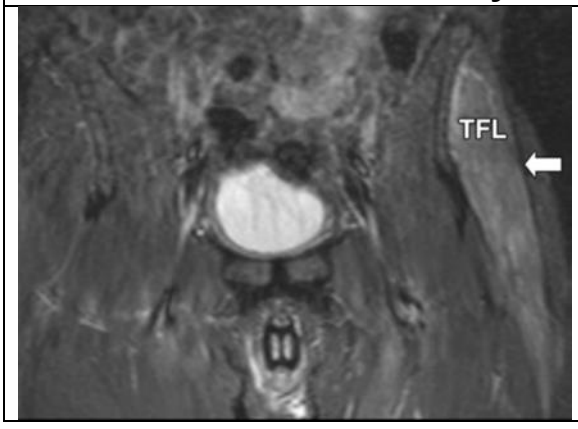
Causes:

- ***Total hip replacement***: is most well-recognized cause of superior gluteal nerve injury.
- Complication of percutaneous placement of iliosacral screws

Muscles Distribution:

- **Gluteus minimus**
- **Gluteus medius**
- **Tensor fascia lata**

❖ ***Denervation edema of Tensor Fascia Lata***



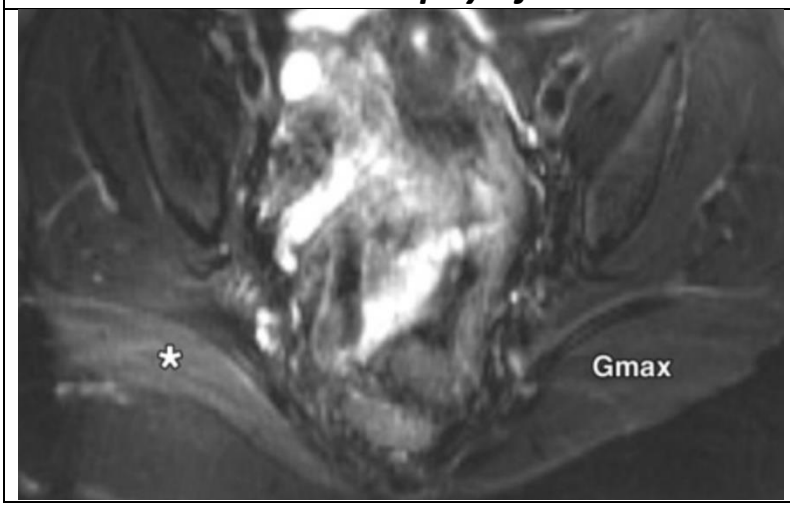
D- Inferior Gluteal Neuropathy

- It exits the pelvis through the greater sciatic foramen
- Inferior to the piriformis muscle.
- Divides into upward and downward diverging branches, which enter the gluteus maximus.

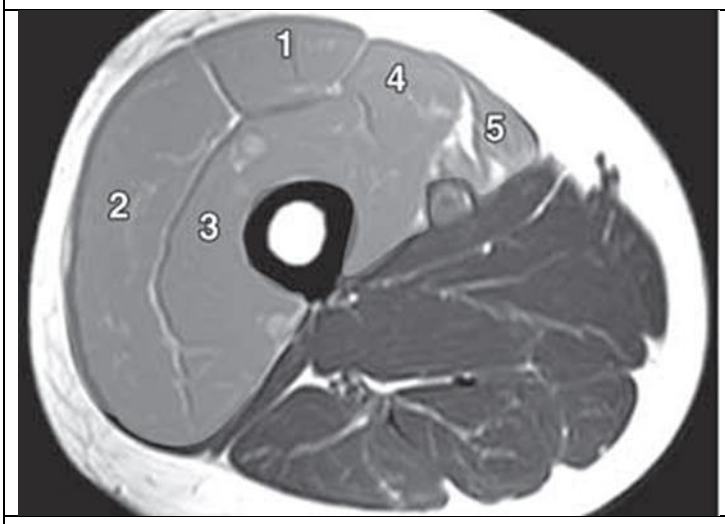
Cause:

- Inferior gluteal entrapment neuropathy is rarely reported but is recognized as a complication of the posterior approach to hip arthroplasty.

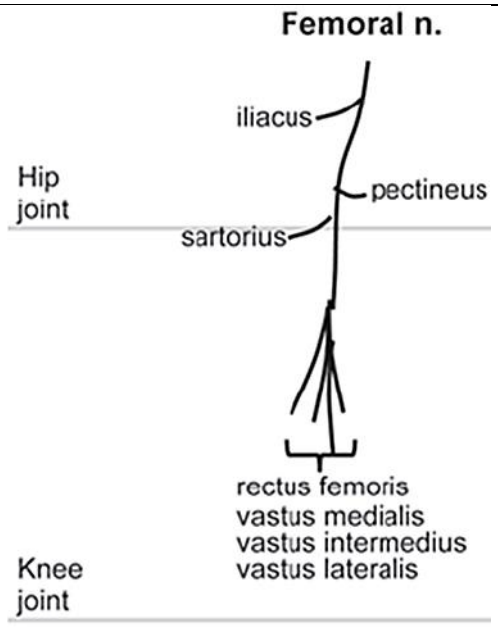
❖ ***Denervation Atrophy of Gluteus Maximus***



E- Femoral Nerve



1 = Rectus Femoris
2 = Vastus Lateralis
3 = Vastus Intermedius
4 = Vastus Medialis
5 = Sartorius



Clinical Picture:

- Decreased knee extension (quadriceps weakness)
- Decreased hip flexion (iliopsoas muscle weakness).
- Diminution of the knee-jerk reflex.
- Sensory deficits in anterior and medial thigh and medial knee, leg, and foot

Muscles Involved:

- Iliacus
- Pectineus
- Sartorius
- Quadriceps muscles

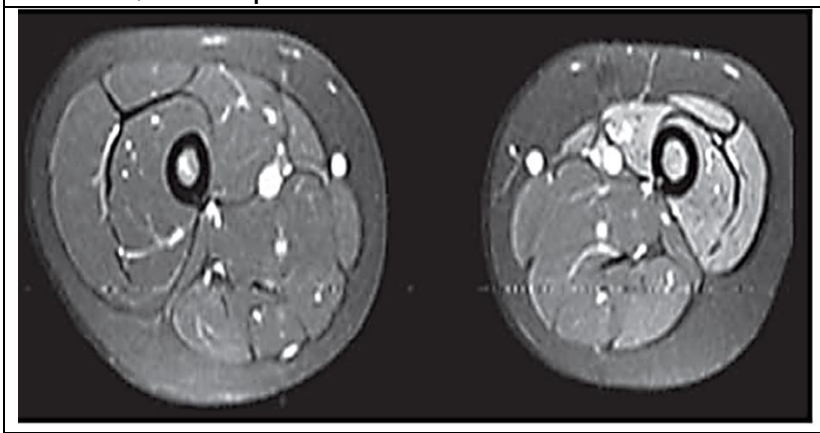


Figure 15. Femoral nerve denervation pattern in a 9-year-old girl after left inguinal herniorrhaphy. Axial gadolinium-enhanced fat-suppressed T1-weighted MR image (550/12) of both thighs shows decreased muscle volume of the left quadriceps femoris and sartorius, both of which demonstrate diffuse contrast enhancement.

F- Common Peroneal Nerve

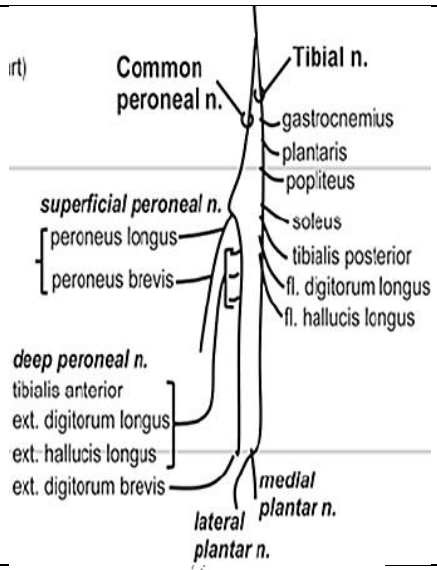
Common Peroneal Nerve Divides Into The Superficial And Deep Peroneal Branches:

Superficial peroneal branch supplies the peroneal muscles in the **lateral compartment** of the leg:

- Peroneus longus.
- Peroneus brevis.

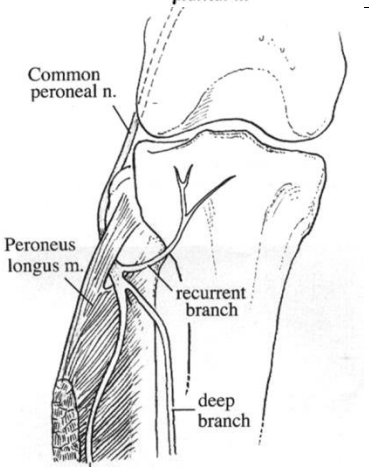
Deep peroneal branch supplies the extensor muscles in the **anterior compartment** of the leg:

- Tibialis anterior
- Extensor hallucis longus
- Extensor digitorum longus



Sites and causes:

- Compressed at ***fibular neck***
- The peroneal tunnel is between the two heads of peroneus longus muscle



Clinical Picture:

Sensory:

- Pain and tenderness at the peroneal tunnel
- Pain in the antero-lateral leg and dorsal foot.

Motor:

- Weak dorsiflexion, inversion
- ***Foot drop and slapping gait.***
- Dynamic compression:
  - Repeated inversion as running or using pedals.

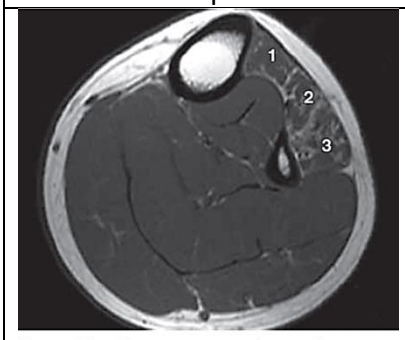
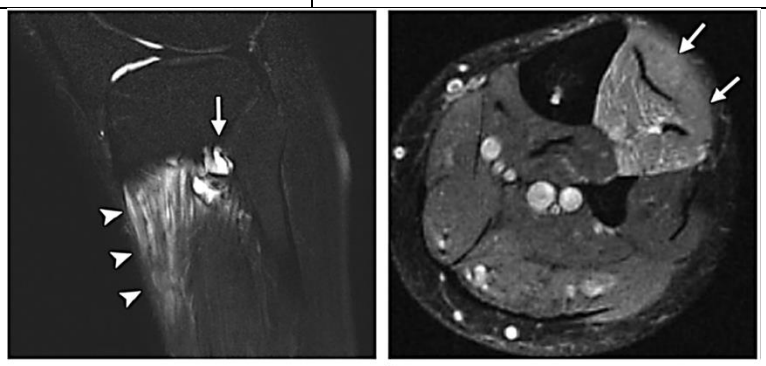


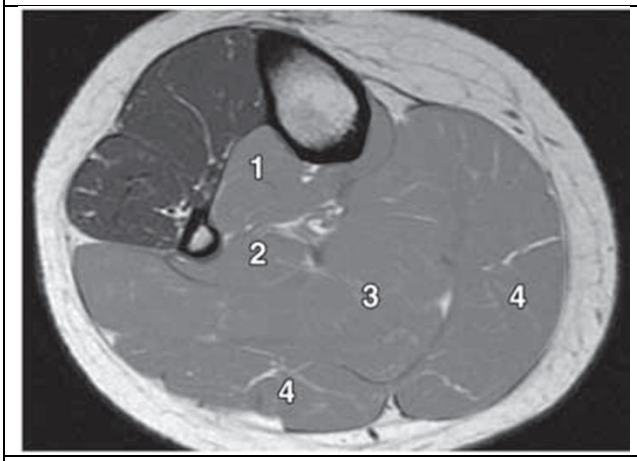
Figure 19. Common peroneal nerve denervation pattern in an 18-year-old man with left foot-drop. Axial T1-weighted MR image (500/9) shows fatty atrophy of the tibialis anterior *(1)*, extensor digitorum *(2)*, and peroneus longus *(3)*.



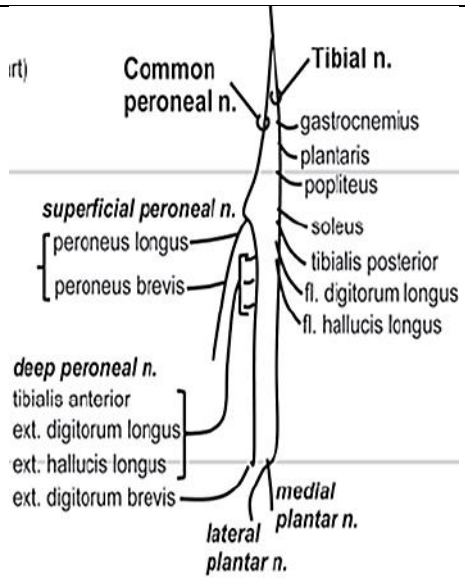
a. b.

Figure 3. Common peroneal neuropathy secondary to a ganglion of the proximal tibiofibular joint.

G- Tibial Nerve Denervation



1 = Tibialis posterior
2 = Popliteus
3 = Soleus
4 = Gastrocnemius



1) Proximal Tibial Neuropathy

Causes:

- Different types of knee injuries, such as a fracture
- Compression by a Baker cyst
- Nerve sheath tumor
- Vasculitis- related neuropathy, such as diabetes mellitus or polyarteritis nodosa

MOTOR innervations to:

- Gastrocnemius
- Plantaris
- Popliteus
- Soleus
- Tibialis Posterior
- Flexor Digitorum Longus
- Flexor Hallucis Longus.

Sensory change on the bottom of the foot and weakness of the plantar flexor and inverter muscles and of the intrinsic muscles of the foot

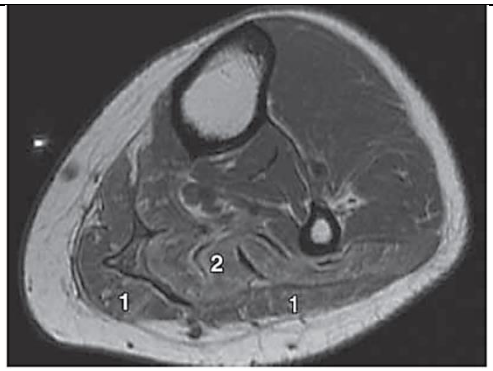


Figure 18. Tibial nerve denervation pattern in a 78-year-old man with left calf atrophy. Axial T1-weighted MR image (700/11) of the lower part of the left leg shows fatty atrophic changes of the gastrocnemius *(1)* and soleus *(2)*.

2) Tarsal Tunnel Syndrome

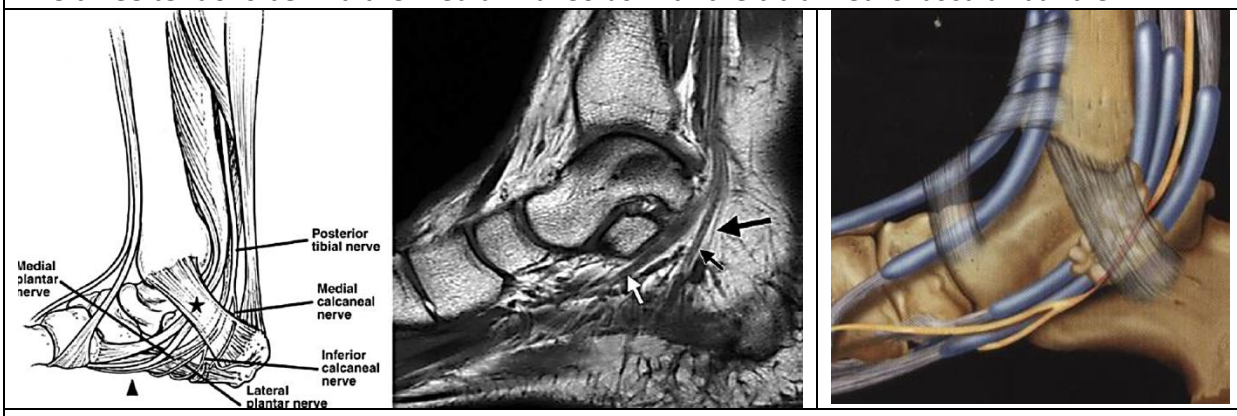
- Pain resulting from compression of posterior tibial nerve as it passes through tarsal tunnel.

Tarsal tunnel is formed by

- The medial surface of the distal tibia, Talus, Calcaneus,
- The sustentaculum tali
- The flexor retinaculum.

It contains:

The three tendons behind the medial malleolus with the tibial neurovascular bundle.

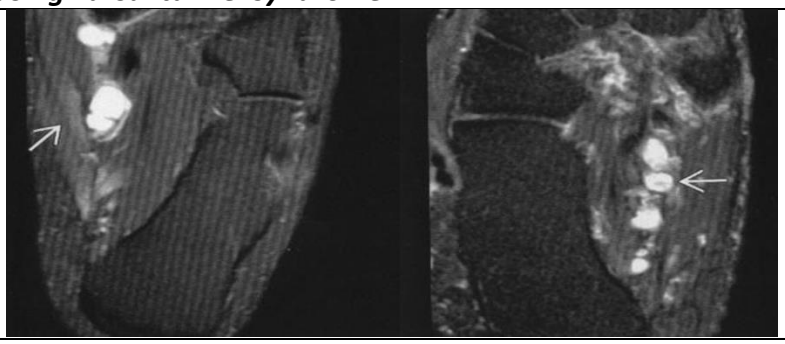


Clinical Picture:

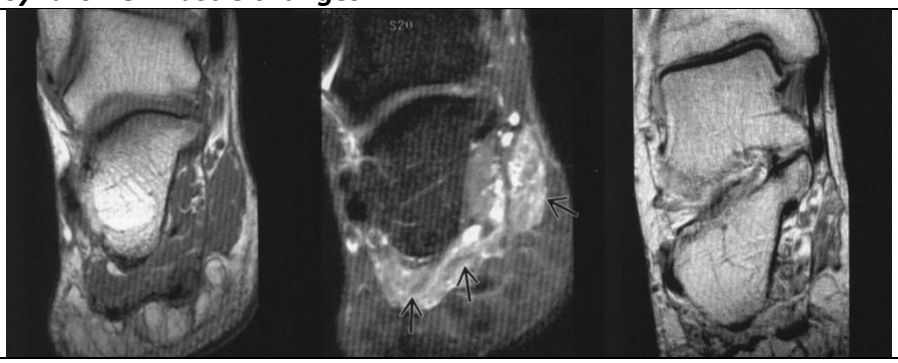
- The patient presents with pain and paresthesia along the medial aspect of the heel and plantar surface of the foot.

D.D.: Plantar fasciitis- Calcaneal bursitis- Tenosynovitis

Varicose veins causing Tarsal tunnel syndrome



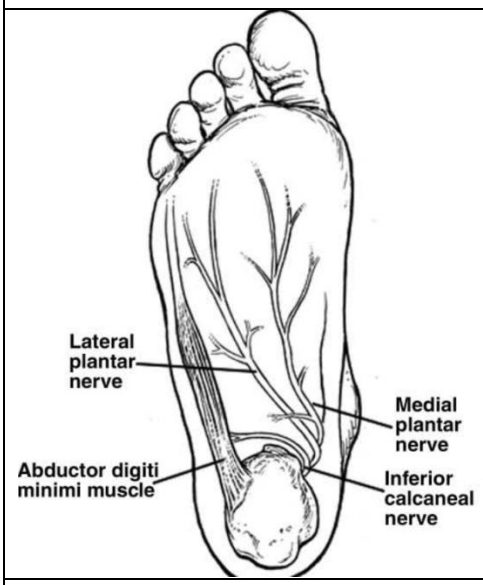
Tarsal tunnel syndrome- muscle changes



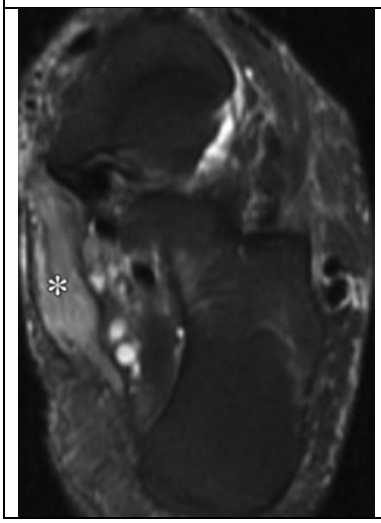
3) Medial Plantar Neuropathy

- Entrapment of the medial plantar nerve can occur at the tarsal tunnel or distal to it, at the level of the Henry knot, between the navicular tuberosity superiorly and the abductor hallucis muscle belly inferiorly.
- Jogger's foot can develop at the Henry knot owing to repetitive trauma to the nerve, especially while running with increased heel valgus and foot pronation.
- Patients usually present with heel and arch pain, tenderness and a positive Tinel sign posterior to the navicular tuberosity, and numbness along the medial plantar foot.

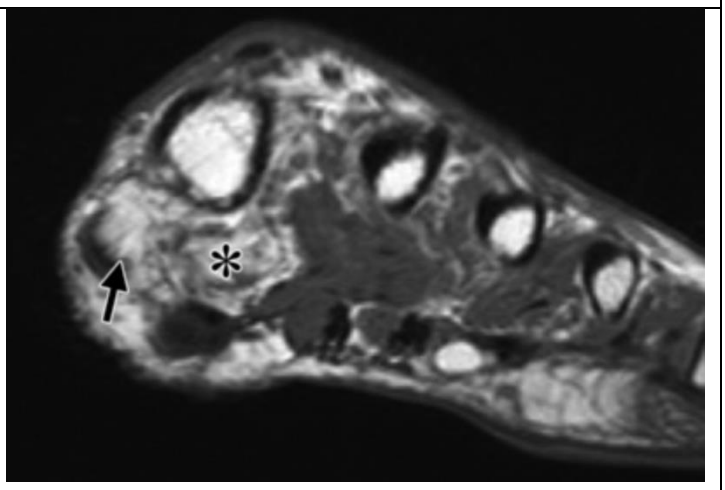
Normal Medial & Lateral Plantar Nerves



Denervation edema of Abductor Hallucis Muscle



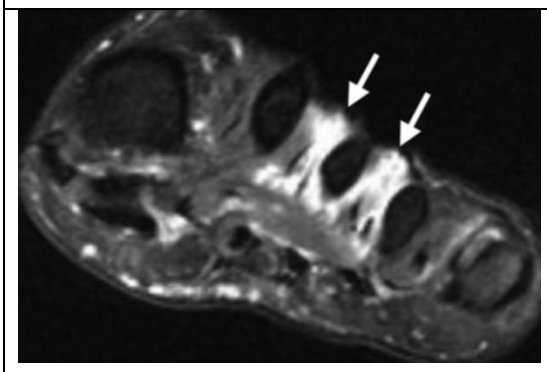
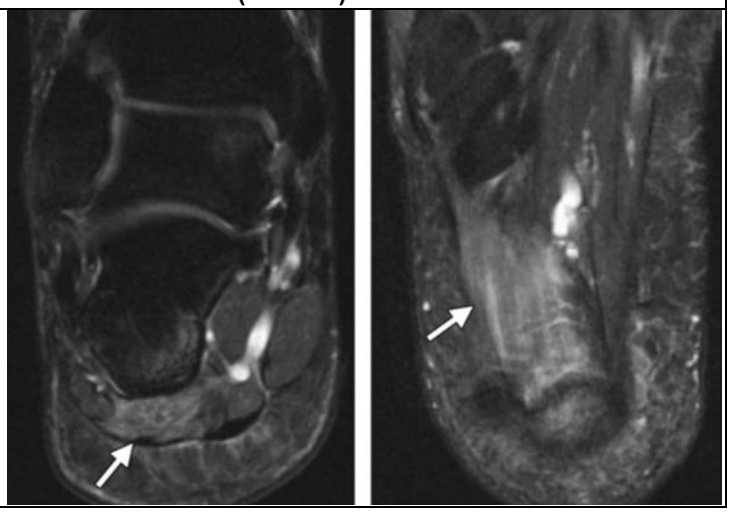
and Flexor Hallucis Brevis (*).



4) Lateral Plantar Neuropathy

- The lateral plantar nerve may be compressed at or distal to the tarsal tunnel.
- The most common symptoms include sensory abnormalities involving the lateral one-third of the plantar aspect of the foot.
- Weakness of the abductor digiti minimi may also be present but is difficult to detect clinically.
- Entrapment of the inferior calcaneal nerve, the first branch of the lateral plantar nerve, often manifests as chronic heel pain that may be mistaken clinically for plantar fasciitis

- MRI: lateral plantar neuropathy may manifest as denervation-related increased signal intensity or atrophy of the intrinsic foot musculature

Denervation Edema of 2nd and 3rd interosseous muscles	Neuropathy of the inferior calcaneal nerve (Baxter neuropathy). Denervation changes in the abductor digiti minimi muscle (arrow).
	

5) Morton Neuroma

- Misnomer; non-neoplastic; does not represent a true neuroma
- Perineural fibrosis around a plantar digital nerve of the foot.
- The condition is thought to be due to chronic entrapment of the nerve by the intermetatarsal ligament

Location

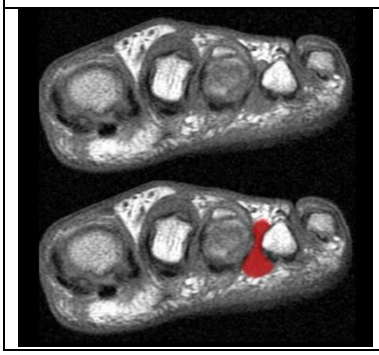
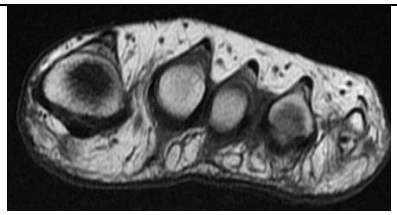
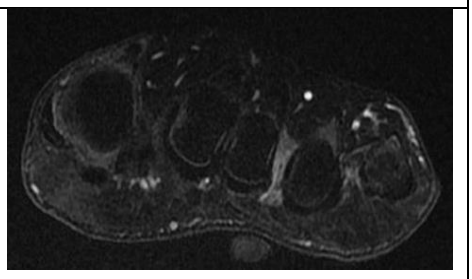
- 3rd web-space (between 3rd and 4th metatarsal heads) is most commonly affected site.
- 2nd web-space is less often involved
- The remaining web-spaces are rarely involved

MRI:

- T1: typically low-to-iso signal
- T2: typically low signal but can sometimes be intermediate in signal
- T1 C+ (Gd): tends to show intense enhancement

Differential Diagnosis of Metatarsalgia / Fore Foot Pain:

- Morton Neuroma
- Intermetatarsal bursa/bursitis
- Metatarsophalangeal joint synovitis/capsulitis
- Changes secondary to a plantar plate tear/disruption
- Metatarsal stress injury / fracture
- Soft tissues tumours, e.g. Schwannoma

Coronal T1	Coronal T2	Coronal T1 FS +C
		

6) Medial Plantar Proper Digital Neuropathy (Joplin Neuroma)

- Joplin neuroma is entrapment neuropathy of the plantar proper digital nerve, a terminal sensory branch arising from themedial plantar nerve.
- The plantar proper digital nerve pierces the plantar aponeurosis and supplies the flexor hallucis brevis muscle.
- Joplin neuroma is rare but may be seen in athletes who perform pivoting activities (such as in soccer and ballet), which cause increased pressure on the first metatarsophalangeal joint

H- Sural Neuropathy

- The sural nerve is a pure sensory nerve, typically formed by the joining together of the medial sural nerve (a branch of the tibial nerve) and either the peroneal communicating nerve or the lateral sural cutaneous nerve (branches of the CPN)
- In the distal leg, the sural nerve courses along the midline, lateral to the Achilles tendon.
- In the ankle and foot, it courses superficial and posterior to the peroneal tendons
- The nerve supplies sensation to the lateral aspect of the ankle and foot up to the base of the fifth toe.

Causes:

- Trauma, such as direct contusion or fracture of the distal fibula, talus, calcaneus, or base of the fifth metatarsal.
- Lateral ligamentous or peroneal tendon surgery may also injure the sural nerve.
- Severe ankle sprains
- Gastrocnemius tear
- Tendinosis of the peroneal or Achilles tendon, and space-occupying lesions.

Clinical Picture:

- Pain and parasthesias along the lateral foot, which are often worse at night and are exacerbated by exercise.
- At examination, symptoms can be provoked by plantar flexion and inversion of the foot.
- MR imaging may help identify the site of entrapment and the potential cause.

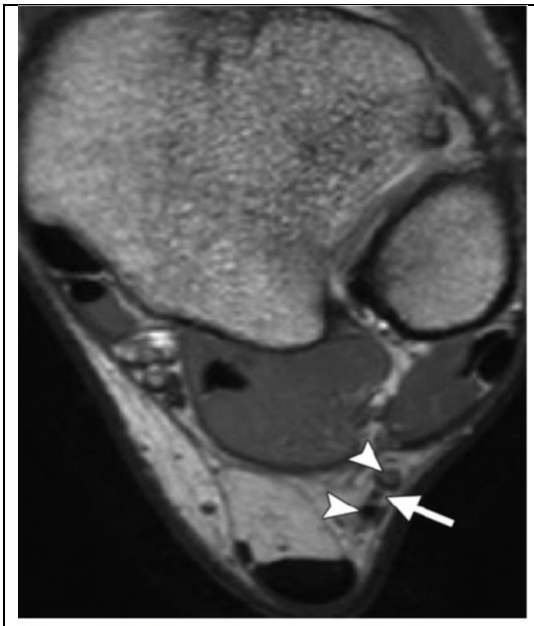


Figure 25. Normal sural nerve. Axial proton density–weighted MR image shows the sural nerve (arrow), which is deep to and between the subcutaneous vessels (arrowheads).

a.

b.

Figure 26. Formation of an adventitial bursa along the sural nerve distribution after malunion of a fifth metatarsal fracture. (a) Sagittal T1-weighted MR image of the fifth metatarsal shows a fracture (arrow) and a plantar bursa (arrowhead). (b) Short-axis T1-weighted MR image of the metatarsal bases shows the lateral adventitial bursa (arrowhead) in the expected location of sural nerve branches.

Musculoskeletal Disorders in Diabetes

Muscle Complications:

- Diabetic Muscle Ischemia
- Infectious Pyomysitis
- Inflammatory Myositis (Polymyositis / Dermatomyositis)
- Muscle Denervation
- Acute compartment syndrome (Vascular / Exertional)

Bone Complications:

- Diabetic pedal osteomyelitis
- Neuropathic Osteoarthropathy (Charcot Joint)
- Infected Neuropathic Osteoartheopathy.

Spine Complications:

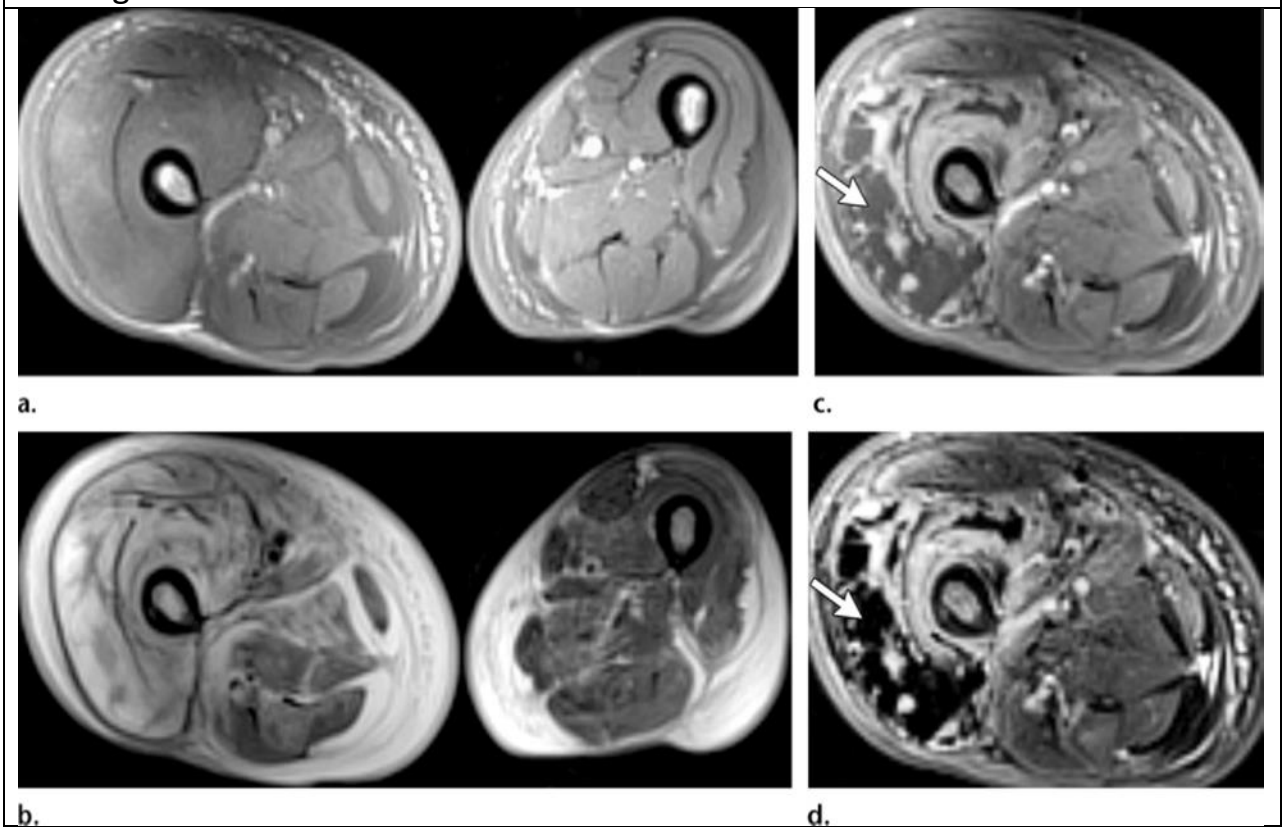
- Dialysis-associated Spondyloarthropathy
- Pyogenic Spondylodiscitis
- Neuropathic spine = Charcot spine

1) Diabetic Muscle Infarction = Diabetic Myonecrosis

- Aseptic or ischemic myonecrosis
- Muscle necrosis, infarction, hemorrhage and focal fibrosis.
- Muscle Pain + Swelling
- NO Fever + NO leukocytosis
- T2/STIR: Muscle edema + Enlargement.
- +C: NO Enhancement.
- Self limited and respond to conservative TTT

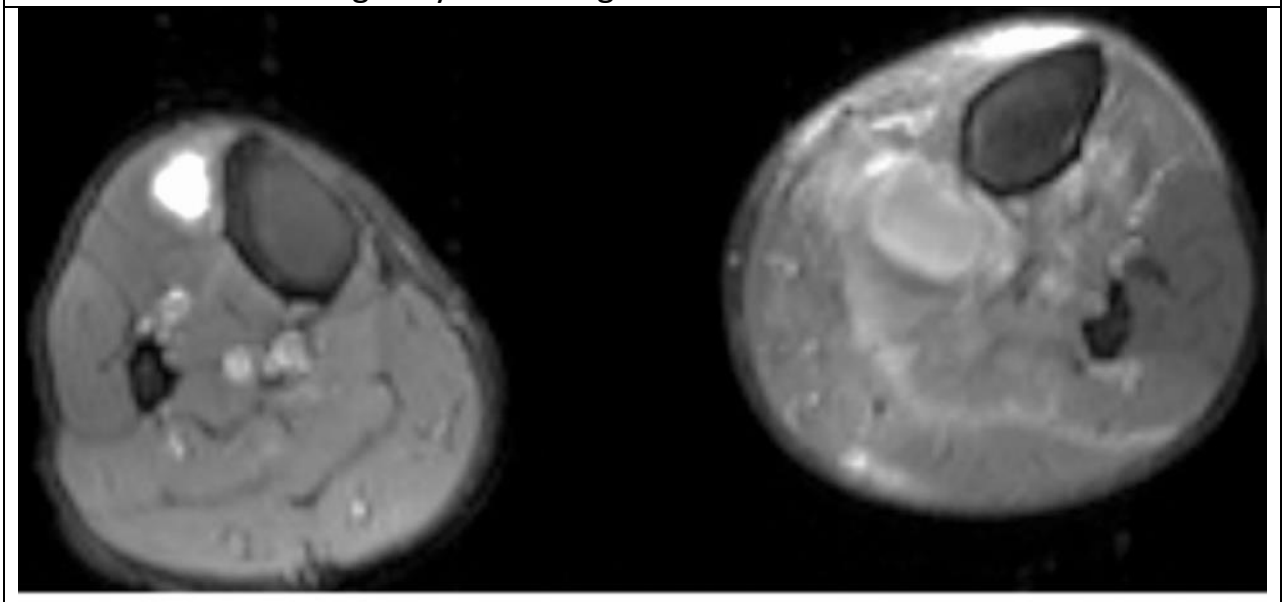
Location & Distributions:

- Thigh and calf muscles.

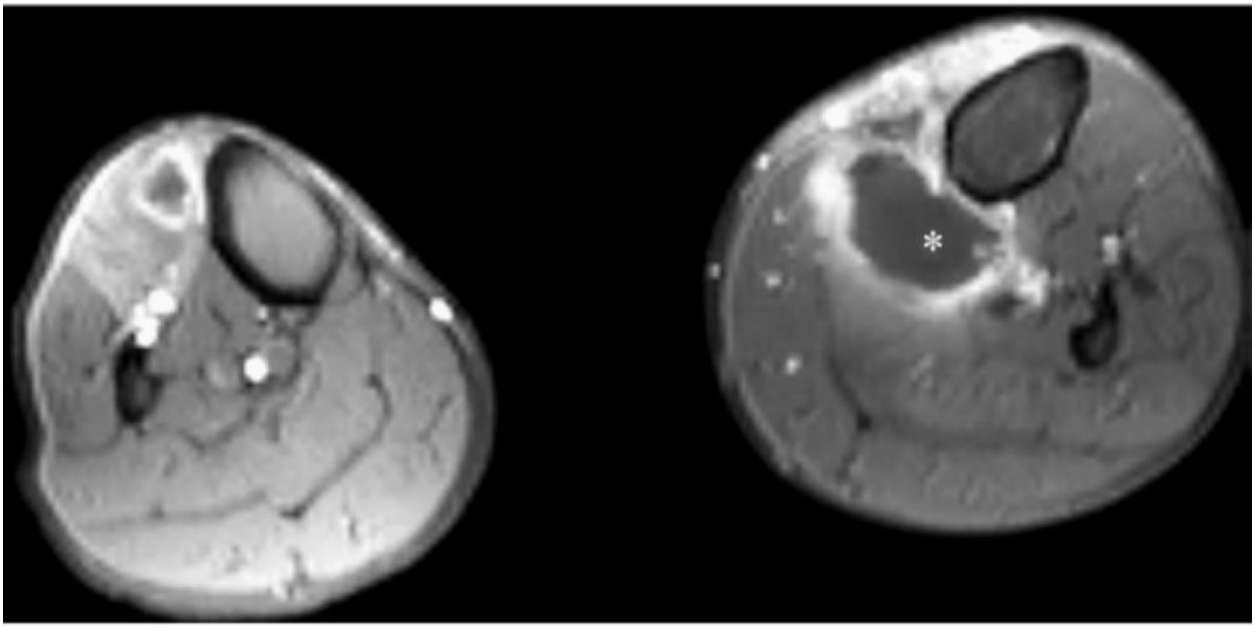


2) Infectious Pyomyositis

- Result from hematogenous spread of bacteria to muscle.
- Cl/P: Muscle pain + Fever + Leuckocytosis
- T2/STIR: muscle edema + Enlargement.
- A well defined marginally enhancing smooth walled intramuscular abscess.



a.



b.

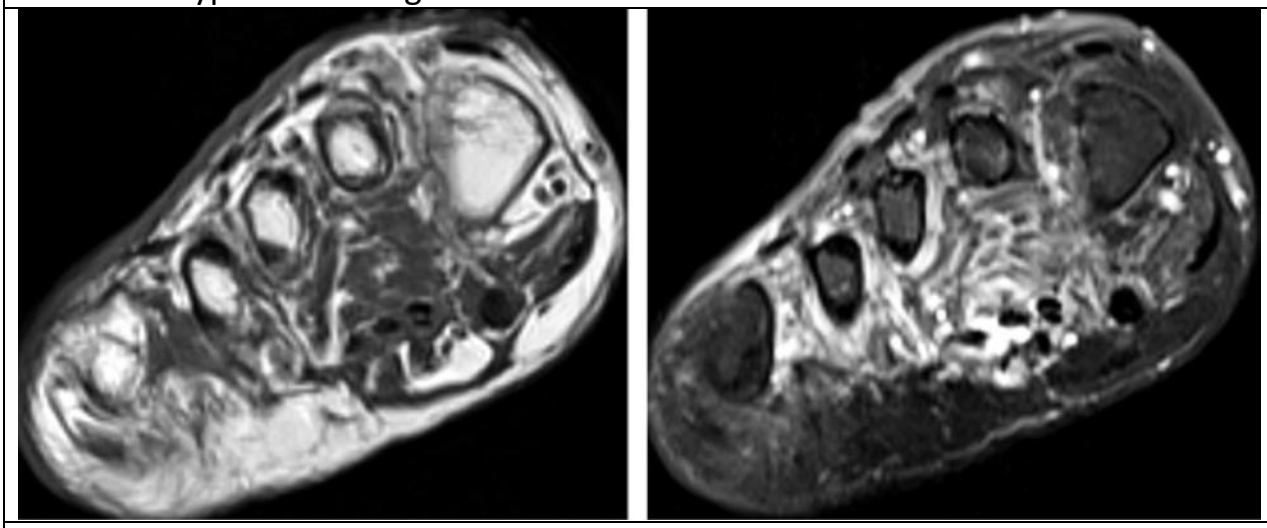
3) Muscle Denervation

Acute / Subacute muscle denervation:

- Swollen muscle + edema
- T1: Normal
- T2: hyperintensity in the affected muscles

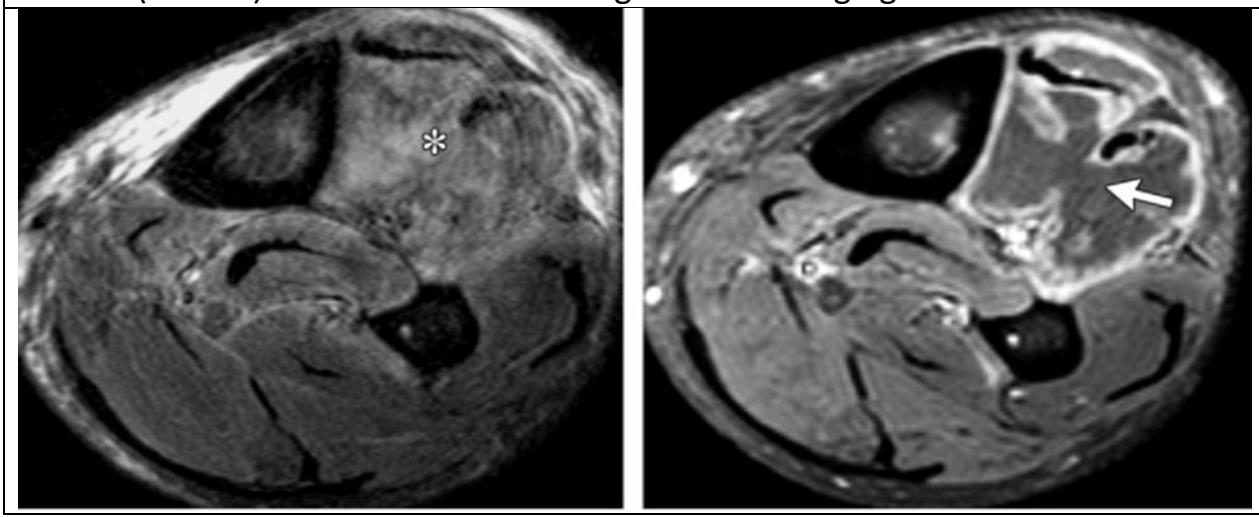
Chronic muscle denervation:

- Reduced bulk + fatty infiltration
- T1: Hyperintense signal



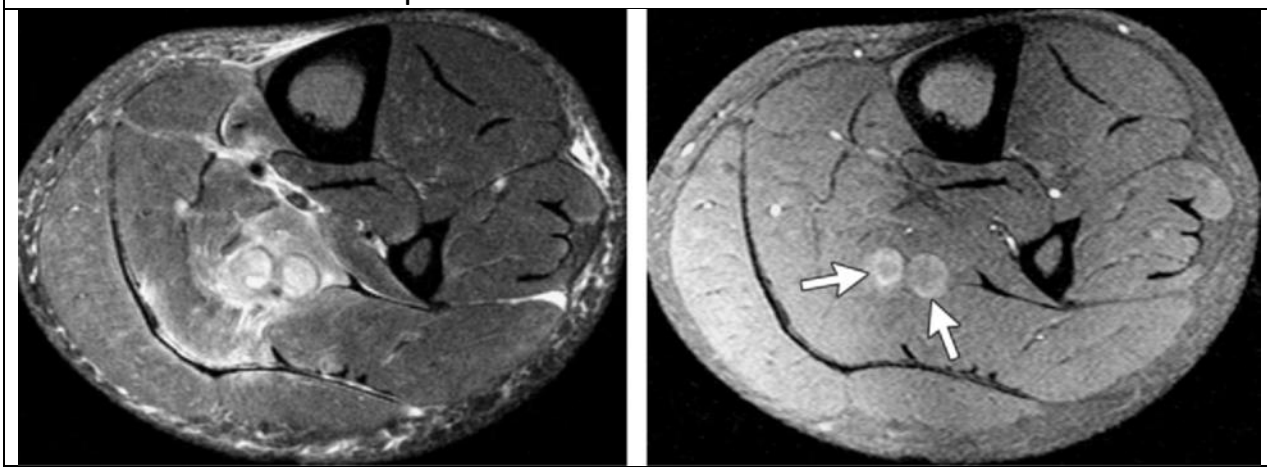
4) Acute Compartment Syndrome

- Manifest with unilateral thigh or calf pain and swelling
- MRI (as DMI): muscle edema + Enlargement => Bulging fascia



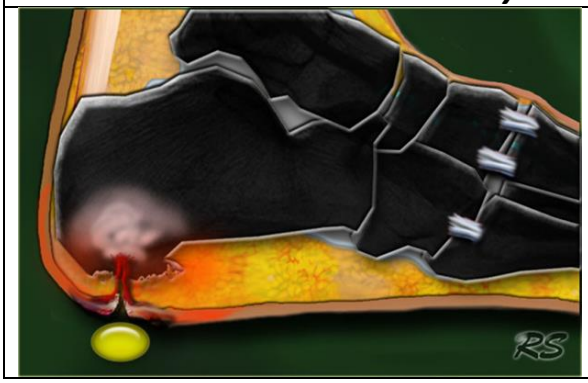
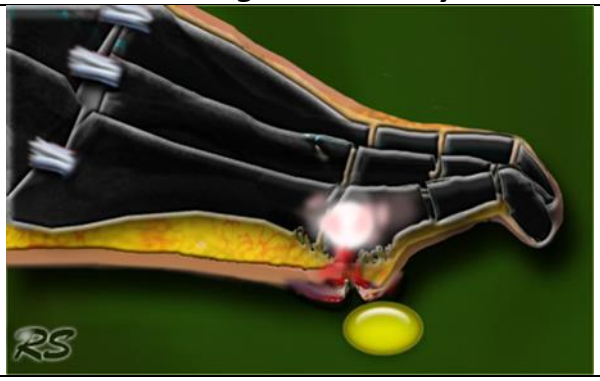
5) DVT

- Unilateral muscle pain + Swelling
- T2 (as DMI): edema of deep muscle and fascia
- T1: Thrombosis of deep calf veins

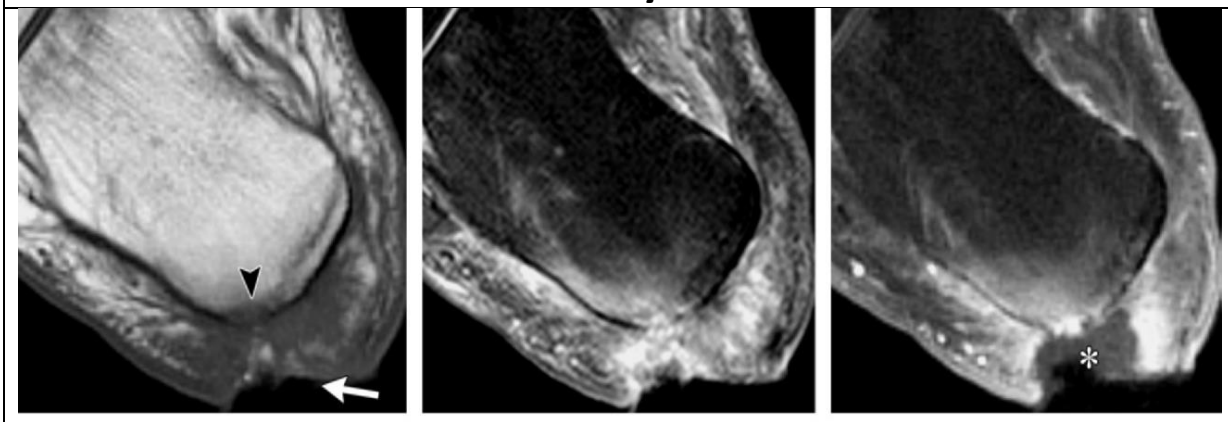


6) Diabetic Pedal Osteomyelitis

- Pressure Ulcers: Fore foot / Hind foot
  - Plantar aspect of the 1st and 5th metatarsal heads
  - Tip of the distal phalynx of big toe.
  - Dorsal aspect of the claw toes
  - Heel
- Soft tissue edema
- Bone Marrow edema:
  - T1: Hypointense signal
  - T2: Hyperintense signal
- +/- Cortical destruction.

Hind Foot => Calcaneal Osteomyelitis	***Fore Foot => Big toe osteomyleitis***
	

Hind Foot => Calcaneal Osteomyelitis



a. b. c.

Fore Foot => Big toe osteomyelitis

7) Neuropathic Arthropathy

- The term neuropathic arthropathy or Charcot joint is applied to all articular abnormalities related to central or peripheral neurologic lesions.

Predisposing Factors:

- Diabetes Mellitus
- Tabes Dorsalis
- Syringomyelia
- Meningomyelocele
- Multiple Sclerosis
- Trauma
- Alcoholism
- Amyloidosis

Pathogenesis

Loss of deep sensation and proprioception + Recurrent injury

Most Common Site:

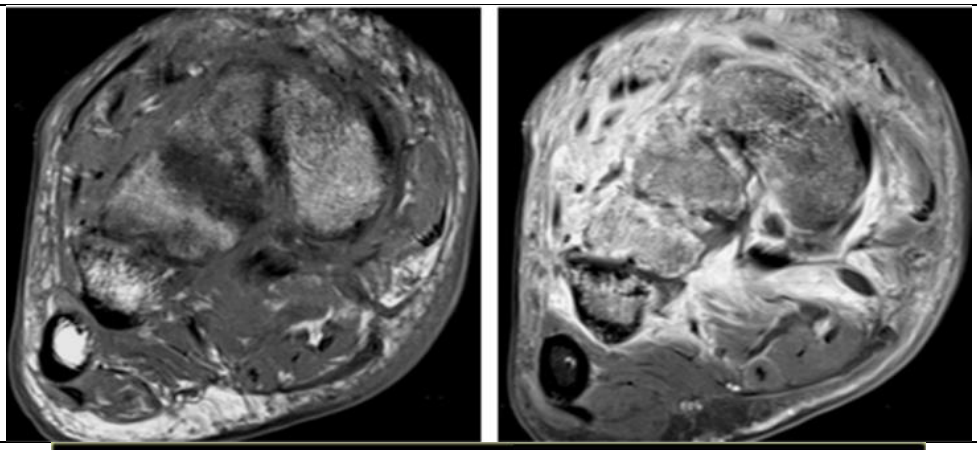
- Shoulder - Syringomyelia
- Hip – Syphilis and Spinal dysraphism
- Knee – Syphilis and Diabetes
- Foot midfoot (subtalar, intertarsal, and tarsometatarsal joints)– Diabetes
- Spine – Spinal dysraphism

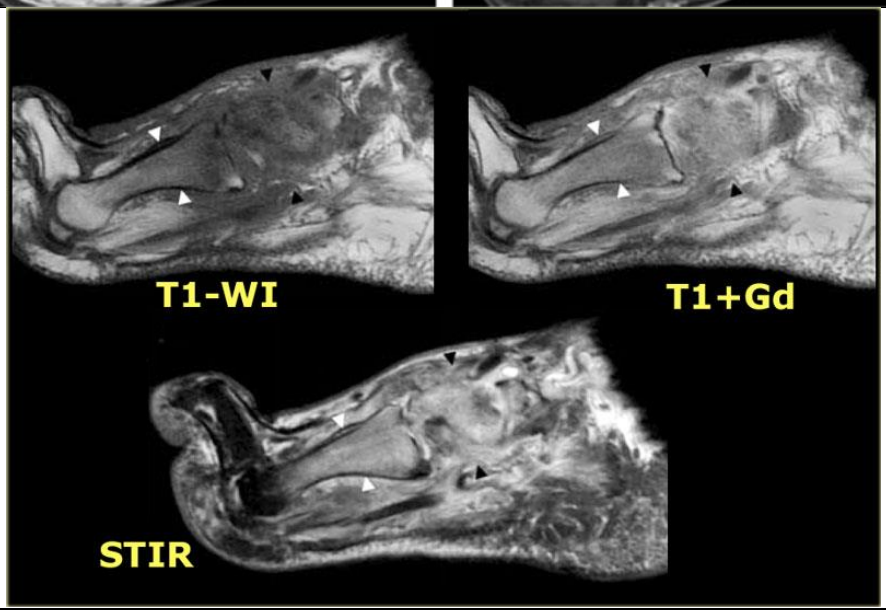
Acute Neuropathic Osteoarthropathy

- NO ulcer
- Soft tissue edema
- BM edema
- Subchondral cysts
- Subchondral erosions
- Joint effusion

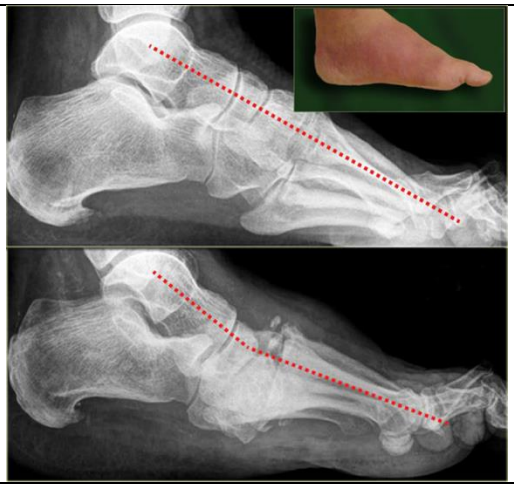
Chronic Neuropathic Osteoarthropathy (Charcot Joint) = 6Ds

- Distended joint = joint effusion
- Density increase = Bone sclerosis
- Debris production
- Destruction
- Dislocation = Lis-franc dislocation
- Deformity = Rocker-bottom deformity

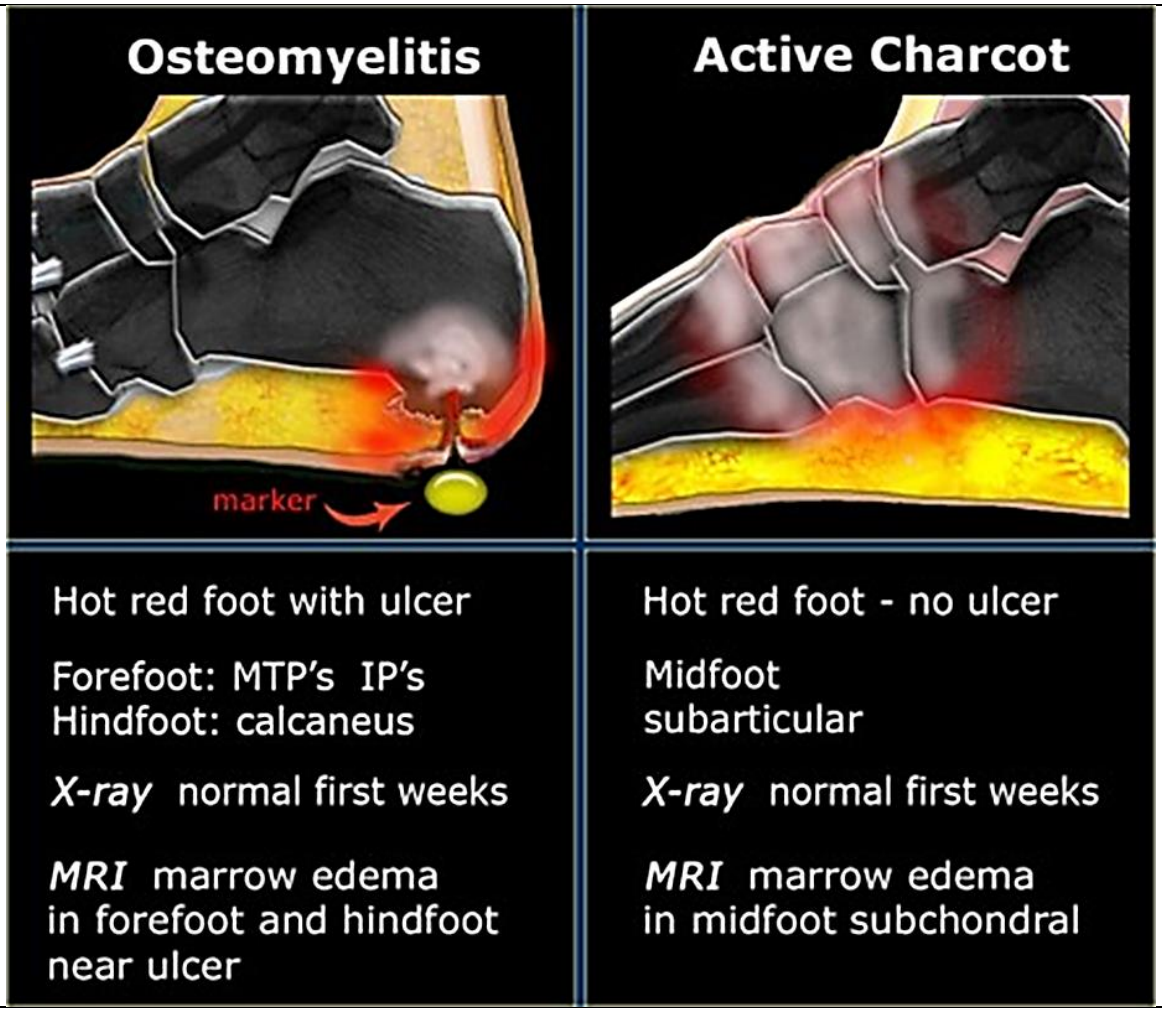




Rocker-bottom deformity

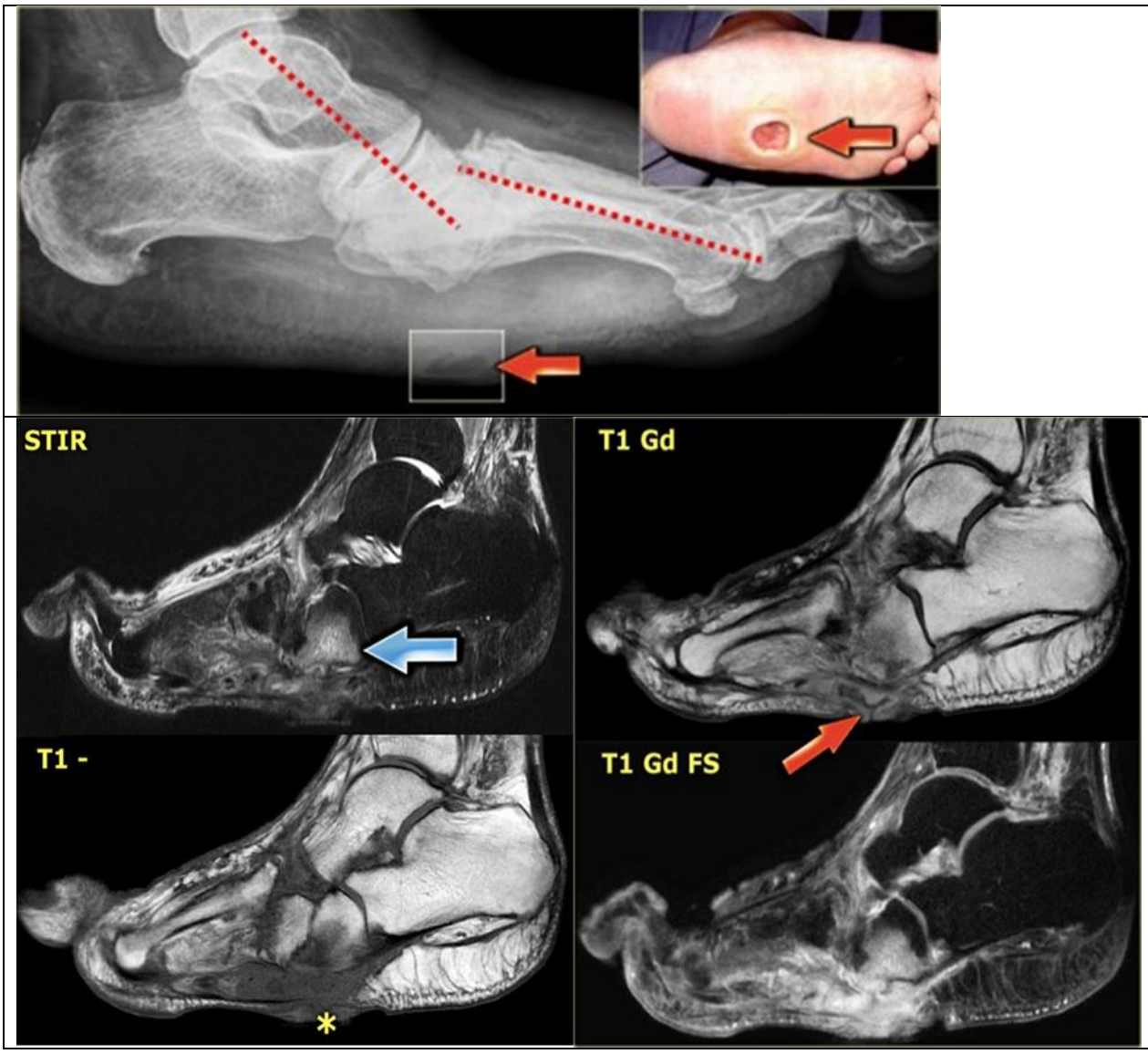


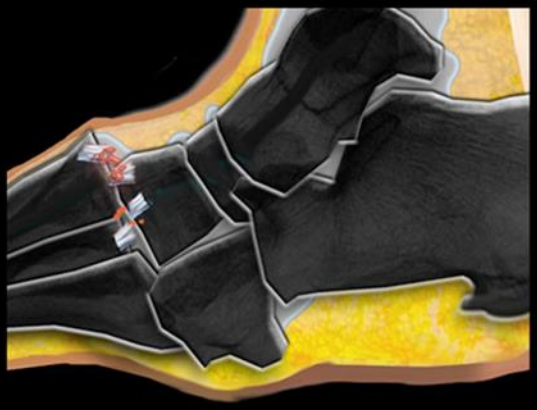
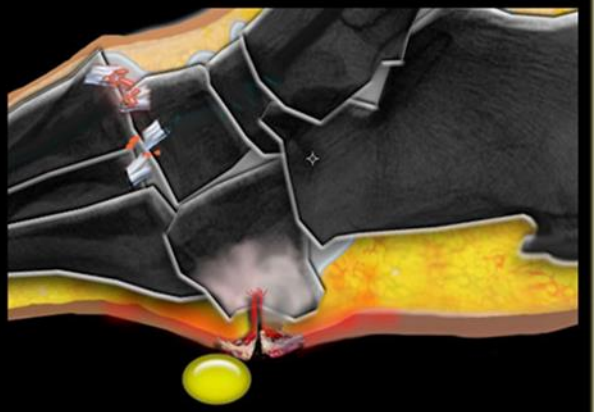
Lis-franc dislocation



8) Infected Neuropathic Osteoarthropathy

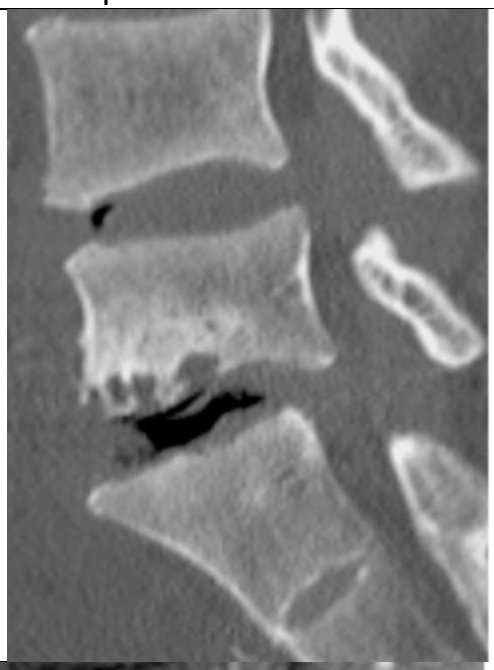
- The deformities caused by chronic neuropathic osteoarthropathy predispose the patient to ulcer formation in the midfoot, which is otherwise an unusual site of ulceration.
- Neuropathic Osteoarthropathy (Charcot joint) => Rocker-bottom deformity => Midfoot Ulcer => Mid foot Osteomyleitis on top of Neuropathic osteoarthropathy

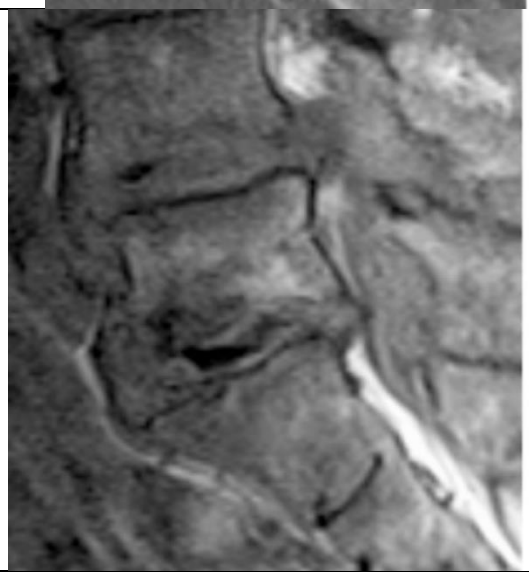


Chronic Charcot	Superimposed infection
	
Swollen neuropathic foot no ulcer	Hot red foot with ulcer or sinus tract
X-ray Joint deformity dislocation Rocker-bottom	*X-ray* Joint deformity dislocation Rocker-bottom
MRI no marrow edema	*MRI* marrow edema in cuboid near ulcer

9) Dialysis-associated Spondyloarthropathy

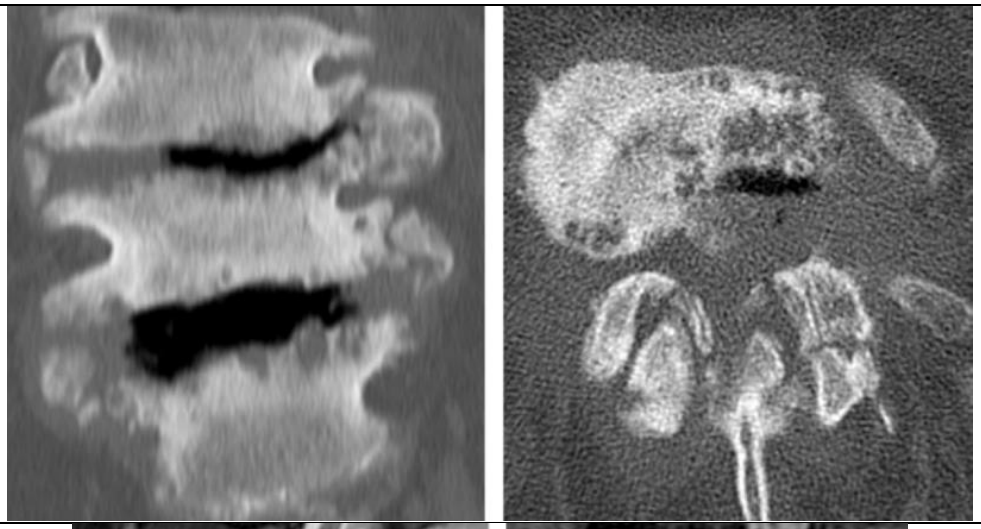
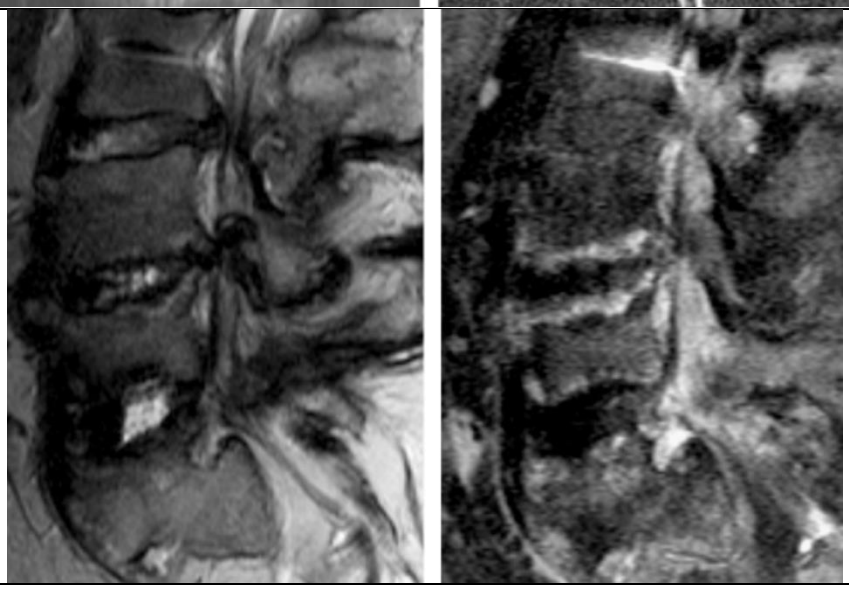
- Intervertebral disk space loss,
- Vertebral endplate erosion and cyst formation,
- minimal formation of endplate spurs
- Subluxation and spondylolisthesis
- Associated perivertebral soft-tissue abnormalities.





10) Pyogenic Spondylodiskitis

- Narrowed disk space
- Decreased T1 signal intensity and increased T2 signal intensity in the affected vertebral endplates and disk.
- Intradiskal fluidlike signal intensity and enhancement.
- Destruction of the neighboring vertebral endplates.
- Paraspinal or epidural phlegmon or abscess

11) Neuropathic Spine = Charcot Spine

- Disc space narrowing and vacuum phenomenon.
- Vertbral osteolysis and osteosclerosis, subluxations, abrupt curvature, and large endplate spurs.
- The joint debris, disorganization, and subluxation seen in the neuropathic spine resemble the features of neuropathic arthropathy in the Charcot foot.
- Facet erosion and subluxation are typical early in the disease process.
- Neuropathic spinal arthropathy usually involves the lower thoracic and lumbar spinal segments.